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CYBERNETICS, COMPUTERS, AND AUTOMATION TECHNOLOGY

MODELING IN THE MILITARY

Simple Simulation Models

Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 3, 1977 signed to press 1 Feb 77 pp 10-11

[Article by Col V. Babich, Col A. Dubovitskiy, Col Ye. Lavrent'yev: "From Copying to Originality"]

[Text] Modeling in the military is employed primarily in three areas: in theoretical research, in studying personnel, and in analysis of the process of warfare. Simulation of flight is closer to the area of training in which a model performs the function of transmission of new knowledge to the pilot. In this article we shall be discussing the model and its copies, stages of simulation, utilization of models in preflight preparation, the diagram and model, and the advantages of simulation as a method of cognition.

Let us begin with the model and its copy. In the process of training, pilots frequently encounter simple models and elementary simulation. This can be demonstrated with the example of ordinary preflight preparation.

According to the schedule, the pilot is to perform two tasks: flight in the training area, and one-on-one free combat. The first task is not new to him. Having thoroughly studied the exercise, the pilot mentally runs through the sequence of performance of individual maneuvers, and then the entire sequence as a whole. He observes his aircraft from a vantage point, as it were, and puts together the complex flight path piece by piece: first the banked turns, then a chandelle, followed by a roll, a loop, additional rolls, and a slow spin.... If difficulties arise at any phase of the mental piloting sequence, he is assisted by methods elaboration of the exercise.

After running it through several times mentally, the picture of the flight becomes firmly fixed in one's mind. Failure to follow the proper sequence of maneuver execution is almost out of the question. During flight, control signals will proceed from the pilot's memory in the requisite sequence. There will be no excessive stress, and the pilot's attention will be fully concentrated on pure performance.

Can we call this effective method of memorization modeling or simulation? At first glance it would seem we can, for the pilot has created a mental analog or a simplified diagram of the flight, and he has performed in the air according to this scheme. However, an informal approach to the question suggests another answer as well.

Modeling is investigation of the properties of an object with its analog, while the process of investigation was lacking in preparing for the training mission. And since the model proper of flight into the training area had already been constructed by the authors of the exercise, had actually been flown and recorded in the training schedule, the pilot merely took a copy of it (which his assignment required), without introducing new elements.

The second flight is more complex, and in preparing for it, it is not enough to memorize or take a copy from a ready model. In free air combat each pilot will seek to be the first to enter the potential attack area and perform the graded sequence. A single goal is pursued, but there are many paths to attain it. These paths intersect. In the preceding flight involving a similar task, the adversaries proceeded right for one another and displayed equal piloting capabilities. Neither succeeded in taking an advantageous position to deliver ordnance, and the engagement ended in a draw. In order to achieve success now, it is necessary to surpass the adversary in tactical sharpness and present him with an unaccustomed problem. In this instance the flight configuration should be made considerably more complex. Needed here is a basic idea which arises as a result of analysis of factual material. Also needed is a close link between the logic of future combat on the one hand and the capabilities of the equipment and achieved level of flight performance on the other.

The theory involved is presented in a textbook, along with the tactical principles and procedure of calculations, but there are no formulas on how to act in each specific instance, nor will there be any. Therefore only well-developed tactical thinking, experience and knowledge can render real assistance.

The pilot takes airplane models and, displacing them in space, seeks possible methods of attaining a position advantage. It is difficult to gain the element of surprise. Therefore emphasis is placed on the feint. It is run through several times until the details have been refined. The adversary's behavior changes in each runthrough. Now begins an investigation and search for something new, that is, precisely those elements of modeling which were absent when preparing for departure to the training area. The results of the search indicate that the maneuver is enticing to the adversary, that one might readily succumb to it, and then miss the attack. A decision has been made -- this is the way to proceed.

Calculations establish a rigorous sequence of combat maneuvers and the actual contours of the entire flight path. The selected variant is substantiated in its principal parameters and differs significantly from the initial one. The pilot has added to his tactical arsenal and has taken a

step toward the summit of combat skill. This is movement forward, the achievement of a new position in the art of winning.

What is the main distinction between preparation for the second flight and preparation for the first one? As we have already noted, it lies in utilization of the simulation method, but in addition it also lies in displaying innovativeness, that is, the ability to find a correct solution in nontypical situations. Innovativeness and modeling are inseparably linked.

Let us examine the stages of simulation. In the first phase one selects an analogue for investigation or copying. The pilot assesses the structure of the object and compares it with existing models. In our example another engagement successfully conducted under similar conditions could serve as a model of the forthcoming air engagement. One should understand that there does not exist a complete copy of the flight for working up the elements of combat employment. The concrete situation compels one to make corrections even in an exercise performed for the second time.

During the Great Patriotic War records of the most instructive combat episodes were kept in many units; aircrews turned to these in preparing for their next missions. All useful elements were extracted from accumulated experience for utilization under concrete conditions. The idea of the concept, for example, was taken as a basis, and the diagram of actions would be changed. Successful devices employed in the most recent engagements would also be considered. Therefore the possibility of repetitive pattern was excluded, and it was difficult for the enemy to figure out what the plan was.

In peacetime a pilot can successfully borrow a device from the experience of an exercise, abstract from the specific factors and view this device as an analogue. If there is no ready model of the flight which can be taken as a basis, a new one is constructed. The method of construction depends on the complexity of the task and the time allocated for preparation. The path of the experimental flight, for example, can be fully calculated on a computer and then recorded by monitoring instruments. Specific conclusions are drawn on the basis of comparison. When time is of the essence, only the most critical elements of the flight can be modeled.

In the second phase (studying the model) the pilot's work boils down to seeking the most advantageous (optimal) variant of action within the framework of the assigned task. This is the way it was in our example of preparation for combat. The method of selecting optimal variants (comparison of experiment results) is demonstratively embodied in "walking through the mission," in which each pilot participated.

In the course of experiments -- bringing together and moving apart groups of "aircraft," restructuring formations, combat maneuvers and attacks -- the problems of the actual mission are resolved. After this phase is run through, the commanding officer makes corrections or alters the disposition

of forces in the air. If, for example, in the process of assembly one flight drew too close to another, the entire group returns to the "field," after which they again "take off" at greater time intervals.

Selection of a combat formation corresponding to the character of the assigned task is a process which always involves search. It is difficult to find a ready model for emulation. The pilots of past generations became convinced of this and passed down to succeeding generations the "walking through the mission." Today it is categorized as a component of simulation and most clearly depicts the possibility of studying the properties of a phenomenon on its analogue.

In the third phase (synthesis and concretization of results) one selects data obtained in the investigation and objective appraisal of conclusions. In other words, the expediency of verifying the model in the air is elucidated. The following requirements should be observed: no uncertainties should be left. Usually a principal and alternate variants are chosen, with a rigorously designated sequence of action. Concretization of conclusions is expressed in the flight plan, which is approved by the commanding officer.

It is important to remember that conclusions drawn on the basis of simulation can be recommended for extensive application only following practical verification. A battle won in the classroom by no means signifies a future victory in the air. However, firm prerequisites to achieve success already exist, since the pilot climbs into his cockpit with a ready game plan.

Now let us see how models are utilized in readying for a mission. In the process of practical flight activities, pilots employ various types of models on a daily basis. Models of the gunnery range and aircraft are object (material) models. They are based on geometrical similarity and analogous placement of structural elements and give a graphic picture of the external forms of the actual object. Pilots also frequently utilize tables and nomograms. These store requisite information. Many of them are the result of mathematical or electronic simulation and are called symbol models. Physical models -- gunnery and pilot training simulators which display the behavior of the object -- are extensively employed in the training process. The pilot is subjected, as it were, to conditions close to actual flight, and he even acquires flying or weapons utilization skills. The concept of flight model can best be assimilated on an operating flight simulator.

Frequently pilots use symbols, analogs -- in the process of learning. They are extremely simple and take up little space on paper, but they tell a good deal, provide all the necessary information on the actual object. The most graphic example of a symbolic model is the scheduled table of flight operations, in which a process which is highly complex in organization and execution is depicted with the simplest symbols. The planning table possesses properties which are mandatory for a model. It carries useful information and answers proper questions. The flight operations officer, using the

symbols and the time schedule as a guide, monitors not only the position of aircraft in the air but also the actions of each aircrew.

In addition to everything else, diagrams help pilots study their flight assignment. Frequently attempts are made to call any diagram a model, even a single curved line on a diagram running from an aircraft silhouette to the target. One can of course argue that this is an attack model, but it carries no useful information. A comparison with legitimate symbol models (for example, flight into the zone -- two circles) would not be correct. A diagram may become an attack model if it answers the question: what will happen if there is a change in altitude, speed, bank angle, G load or position of the maneuver initiation point? In other words, if a rapid recalculation of maneuver, transition to a concretely-assigned task is secured. Corrections for actuality can be taken from nomograms attached to the diagram. Then the diagram will provide the pilot with requisite information and even assist in elaborating a new tactical device.

Speaking of modeling a flight, one must discuss the question of notes and consumption of paper. The example of the planning table shows how intelligently one can make use of opportunities to economize in money, time and manpower. Naturally a pilot must resort to notes in order not to overload his memory. But there is a big difference between a symbol model designated for study (group utilization) and sketched for oneself. The former must answer the questions of all, while the latter only those of the single pilot (executor). Experience indicates that, glancing at a brief note, a pilot can give a complete, exhaustive answer. This is better than a vague answer based on a long note. The main thing is that which is contained in the pilot's memory corresponding to a symbol contained in the notebook. Thus the very process of modeling leaves in the memory of the executor not only the status of the object but also its principles of functioning.

In our opinion further elaboration and standardization of symbols -- sources of information -- would be very helpful to a pilot simulating a flight, just as he is assisted by knowledge of the symbols contained on the monitoring instruments, the radar screen or gunsights.

What are the advantages of simulation as a method of investigation and cognition of the new?

Simulation makes it possible to transfer a portion of experiments conducted previously in the air into the classroom or the simulator facility. Frequently a full-scale experiment in the field is very expensive or simply impossible due to the fact that the target item is not accessible to direct investigation, while a model provides an answer which, although incomplete, is adequate for further investigations.

Further, with the aid of simulation one can repeat an experiment again and again, until satisfactory results are achieved (selection of an optimal action variant), while input data and situation can be altered as the executor desires.

In addition, the model is examined in an accessible form, not distorted by random or unnecessary details. Running through the variants of the forthcoming training battle, the pilot eliminates the entire laborious process of flying the aircraft, although in flight it will give him a substantial share of the physical and psychological work load.

Simulation also provides the opportunity not simply to become acquainted with a given phenomenon but also thoroughly to understand its essence. Studying a flight assignment, a pilot cognizes its internal links and complex relationships and achieves a high quality of execution. Finally, the pilot learns in the process of simulation. He enriches his knowledge, expands his horizons and acquires the skills he needs as a specialist and air warrior.

In our opinion the main advantage of simulation is exclusion of the unsubstantiated decision. This is especially important both in practical flying activities and in military affairs in general, for during mental analysis, when making calculations, when seeking an optimal variant it is much simpler for the pilot and commander to be freed from subjective, superficial and inconsistent judgments.

At the same time simulation requires ability and persistence as well as the availability of auxiliary and methods materials. Therefore a certain caution exists toward simulation as toward any new thing. The most typical question is: "Can't it be done more simply?" In this article we have endeavored to show the effectiveness even of the simplest type of modeling. But can one expect simplification of methods of investigation when the process of armed combat proper is becoming steadily more complex?

At the present time there are no military phenomena for the cognition of which simulation would not be applicable. However, it cannot replace all other forms of preparation for a complex task. Construction of a model is pilot innovative intellectual activity, which has become particularly essential in a period of mastery of new equipment. (To be continued)

Optimal Attack Model

Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 4, 1977 signed to press 2 Mar 77 pp 14-15

[Article by Cols V. Babich, A. Dubovitskiy, and Ye. Lavrent'yev: "Searching for a Better Variant"]

[Text] It is advisable to begin mastering simulation in the classroom, since it is in the classroom that pilots acquire or reinforce knowledge in several disciplines concurrently. Playing out concrete situations and decision-making in various roles can be effective methods thereby.

The former is characterized by the fact that the entire controlling role is concentrated in the hands of the commander -- the person in charge of the proceedings. He selects possible situations, alters the tactical situation, states concrete questions and analyzes responses. Relying on his own experience, the commander imposes his viewpoint on the pilot and brings those present to accept his solution. This form of training class is most acceptable in the initial period of training.

When utilizing the second method, the commander merely prepares scenarios and distributes roles. Pilots who have not been assigned roles take part in discussing intermediate decisions.

In order for truth to be born in innovative debate, the selected maneuver (device, mode of attack) is appraised from the standpoint of the capabilities of the equipment, aerodynamics and tactical expediency. Ready models elaborated by role executors can also be presented for group discussion. The leader merely introduces correcting conditions and makes the final summary of the exercise. The initiative is presented entirely to the trainees.

In order to determine the advantages of one model over another, the commander turns to his experience or suggests performance of calculations of probabilities of air defense penetration and of target destruction. Assessment and comparison of variants on the basis of quantitative indices is much more accurate and objective, but it requires employment of mathematics. Therefore it is essential to take into consideration the group's preparedness to perform calculations as well as the possibility of utilization of simple formula relations or ready nomograms.

As the pilot acquires simulation skills, the tactical problems should be made more complex. The selected situations should be more difficult to analyze. But the executing individual now has the opportunity to link his actions not only with guideline documents and manuals but also with previous solutions. There takes place the process of self-education, which is combined with exchange of know-how.

But how is a flight model constructed? In the previous article we examined some features of the process of investigation and stages of simulation. We shall now endeavor to reveal the content of the work performed by the pilot who is simulating a conventional flight problem.

The squadron had gathered in the classroom. The topic to be studied was flight simulation. They were to work with an exercise which included elements of tactics and combat employment. Thus there was observed here a link between theory and practice (objectivication of study). Models (targets) on the gunnery range were selected as analogs of targets and air defense weapons. The pilots were handed diagram cards on which were entered detection zone, automatic tracking zone, "enemy" weapons killing zone, target and battle line. The mission was to be flown in two-aircraft flights. Each flight was to hit the target, independently selecting the mode of attack.

The men are divided up into pairs in conformity with the schedule table.

The pilots may utilize all reference material available in the classroom. Solutions are recorded on the diagram card in written form. The flight leaders report the elaborated variants orally. The instructor compares them and selects the optimal solution on the basis of established criteria. The degree of detailing of the models and the method of assessing them are determined in advance.

As already noted, objectivity of analysis and reliability of conclusions are increased with the availability of quantitative characteristics. If a common variant for all is adopted for execution, it can be comprised of several solutions (after determining the strong points of each).

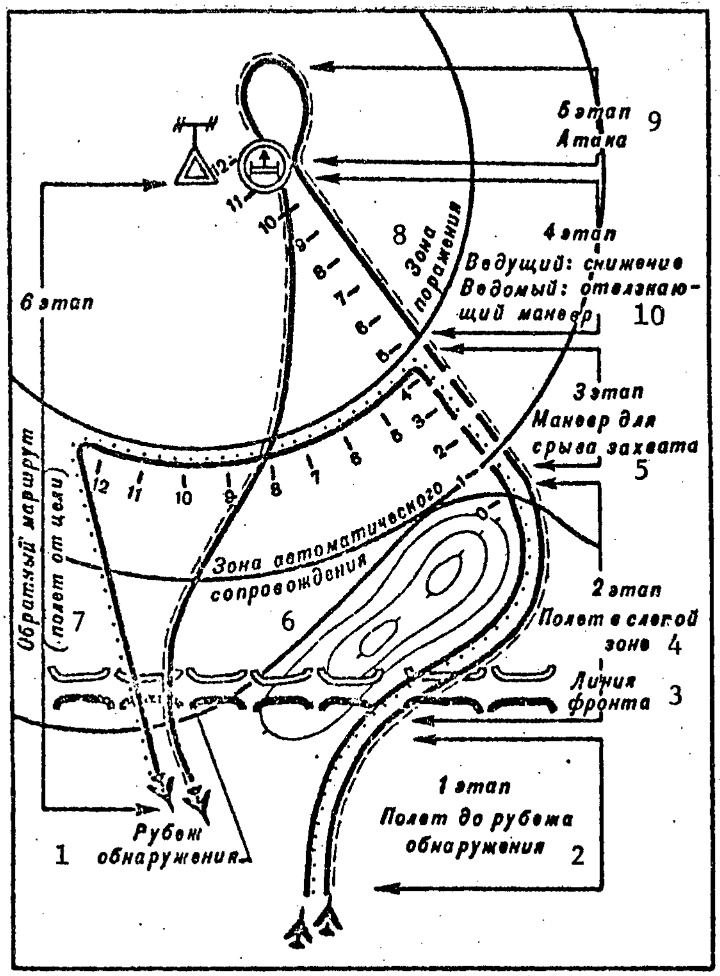
We shall join one of the groups of participants in the exercise and observe its performance.

Following a situation analysis the pilots determine that they are to elaborate an entire complex of devices and run them through on the gunnery range model. Unforeseen situations may arise at each point en route. Even a small error made long before reaching the target area can result in mission failure. In view of these considerations, the trainees break the entire flight down into stages: up to the point of detection by "enemy" radar, in the tracking zone, in the automatic tracking zone, in the killing zone, over the target, and on the return home.

Then the pilots determine what is the most important element at each stage. This investigation device is mandatory in the process of mission simulation. It makes it possible to concentrate attention on the most critical details which influence the end result. In addition sectors are determined where maintaining the planned mission conditions and maneuver parameters should be maximally rigorous (this means that calculations should be precise). Determination of the main element for each stage of a mission is nothing new to a pilot. In our case the main thing at the first stage is fuel economy, at the second -- concealment, at the third -- precision maneuver, at the fourth -- evasive action, at the fifth -- attack in minimum time, and at the sixth -- invulnerability during return to the destination field.

We should draw the particular attention of executing personnel on this stage of the investigation. It is precisely here that the rough model is born, its foundation, its skeleton. In other words the stones are being hewn which will be used to construct the pyramid. Actual construction follows. It is facilitated by the fact that the pilot is already acquainted with concealment measures, maneuvers to thwart lock-on, evasive action and various modes of attack. The principal difficulty in modeling a mission is rational placement of these elements stage by stage as the aircraft advances toward the target.

One must bear in mind that one and the same device may possess different effectiveness in a dissimilar situation. Foreign military experts, discussing the experience of local wars, attest that jamming when flying at low



Mission Model (variant)

Key to diagram: 1 -- point of detection; 2 -- flight to point of detection; 3 -- battle line; 4 -- flight in blind zone; 5 -- maneuver to frustrate lock-on; 6 -- automatic tracking; 7 -- return route (flight from target); 8 -- killing zone; 9 -- attack; 10 -- flight leader: descent; wingman: feinting maneuver; эman -- stage

altitude frequently did not conceal but revealed the presence of an aircraft. A maneuver employed against an antiaircraft system with one guidance system was not suitable for use against another operating on different principles of guidance. A dense combat formation in the detection zone concealed from the enemy the makeup of the attacking group, while in the killing zone it would become highly vulnerable. More examples could be given. They demonstrate the advisability of observing the principle of constructing a model: "At each stage -- the most effective maneuver (device)." This systematization facilitates elaboration of the overall logic and memorization of the sequence of actions in flight without referring to notes.

The first stage of the mission -- up to the "enemy" radar detection zone -- is not particularly complex in execution. In determining flight conditions, a medium altitude is chosen and the most fuel-economical speed. At a calculated point a descent begins, in order to enter the "enemy's" radar-covered zone as late as possible. One should bear in mind that when flying at low altitude an aircraft may not be detected at all by radar (then only three stages will remain -- to the target, over the target, and return).

This mode of mission execution, however, is complex, within the capabilities only of a highly-skilled pilot, and imposes limitations as regards physical work loads. In addition, ground navigation systems cannot be utilized, and arriving precisely on target is little probable.

The stage involving flight in the "enemy" surveillance radar tracking zone involves the necessity of concealing the flight. Concealment can be achieved by utilizing blocking obstacles (shadows) in the radar-covered zone or by concealing the aircraft on a clutter or jamming background. The pilots show preference for the former technique, since on the approaches to the gunnery range there is a hill which provides natural concealment almost up to entry into the automatic tracking zone.

The next, third stage is maneuver to prevent lock-on. The pilots choose from familiar maneuvers -- S-turns (heading maneuver) and alternate overtaking (speed maneuver). A calculation based on nomograms indicates that within the killing zone they can execute three S-turns with a turn of 60° with optimal airspeed and bank angles. Alternating passing offers a smaller probability of lock-on prevention (this applies to the specific system being employed), but requires less time, and the aircraft advance more rapidly toward the target. The pilots choose the latter maneuver. Important here is precise calculation of lead and lag, for disorganized "linking up" will not produce the desired effect.

The fourth stage is flight within the killing zone. Going over elaborated techniques in their minds, the pilots focus attention on vertical and horizontal splitting of the flight. The idea is as follows: immediately prior to crossing into the zone of initiation of fire, the wingman continues flying along the zone boundary (employs a feinting action), while the flight leader descends abruptly to low altitude while continuing to head toward the target. This device is intended to impel the "enemy" fire-control radar operators to track the wingman and lose the flight leader. The flight leader should attack the target at the moment the wingman reaches the maximum parameter. In order to be able to analyze various situations, the lines of possible aircraft track are broken down into minute (or half-minute) segments. At the fifth stage the flight leader attacks the target from a combat turn without a second pass. Withdrawal is in the direction of friendly territory without a climbout. Other techniques are acknowledged to be less effective.

The final stage is the return flight. Proceeding from the situation, it is continued to the point at which "enemy" low-altitude radar tracking terminates.

To prepare a report to the commanding officer, the pilots place the calculated flight path on the diagram card. It is shown in the figure in final form. The entire flight path, from the moment of entry into the "enemy" radar detection zone, is broken down into minute segments. These divisions may prove to be too large, particularly when calculating a flight in hazardous zones.

In spite of the simplicity, a model can answer questions pertaining to a specific mission. We shall enumerate some possibilities. How much time does an aircraft spend over "hostile" territory, and how can this time be reduced? What is the possible result of entering each stage late or early, proceeding from the degree of the "enemy's" readiness to repulse an attack? Is an attack on the target by the wingman feasible? Can a feinting maneuver be dispensed with? Is it not better to execute a "direct penetration" under cover of jamming?

It is important to note that in the given form the model does not answer the following questions: "What is the possible consequence of errors during alternate passing?" and "What will be the consequences of change in parameters of the combat turn?" The pilots studied the mission as a whole and did not elaborate models of combat maneuvers. Modeling of separate mission elements is performed with another method and constitutes a separate topic.

As a rule questions pertain to combat effectiveness, which reflects the results of the strike and the quantity of friendly losses. To answer these questions it may be necessary to refer to graphs or nomograms. The question "how will the probability of penetrating air defense or hitting the target change if..." requires the availability and recalculation of quantitative characteristics. We shall note that it applies more to the forecasting method, although it may be primarily of interest to the commanding officer.

Thus the model depicted in the figure constitutes a reduced-scale flight path projected onto a plane representation of the earth's surface. With this model one can study an actual mission with certain limitations. The pilots had at their disposal a sufficient quantity of informational material and applied a logical-mathematical simulation method. They employed formulas, graphs and nomograms from current manuals. Only maneuver to thwart automatic tracking and feinting action required precise calculation. Can one employ such a model as a foundation in drawing up a "strike delivery" plan? This depends on many factors, and particularly on the urgency and importance of the mission. The pilots of a flight going on a training mission which will be graded consider their variant optimal. The other flights, however, also submit their models for appraisal. They may have a different opinion. On the back cover there is a mission model where the wingman also participates in attacking the target, with an S-turn employed to thwart lock-on. There are seven rather than six phases of the mission. The reader, performing the role of commanding officer, can appraise the advantages and drawbacks of each variant and select the optimal variant.

In conclusion one should discuss the expediency and necessity of modeling each mission. One can express the view that in addition to a test or experimental flight, one must model training flights involving penetration of hostile ground or air countermeasures. It would be useful to elaborate models of the stages of a routine flight, where safety measures should be observed particularly rigorously. As was already noted, relatively simple exercises with stable parameters have been examined in advance and run through in the air. Pilots undergoing training can take a copy from the original.

In our case the enemy is only designated; he does not exert any active countermeasures and does not change his positions. Therefore simple methods of constructing a model were employed. If the opponent may unexpectedly create various threatening situations, and his intentions are not clear, one applies the game modeling method, which we shall discuss in the next article. (To be continued)

Types of Game Models

Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 5, May 77 signed to press 31 Mar 77 pp 10-11

[Article by Cols V. Babich, A. Dubovitskiy, and Ye. Lavrent'yev: "Games Method"]

[Text] Games models pertain to the third area of application of modeling in military affairs -- analysis of the process of combat. It is expedient here to examine their characteristic, distinctive features and types, sequence of construction, the aims and stages of games modeling.

We shall begin with a description of game models. Bilateral tactical exercises can serve as a vivid example of a model-game. But certain conditions must be maintained in order to consider an exercise an analog of forthcoming combat actions: similarity between the practice situation with actual combat, investigative character of exercise (when certain new modes of conducting combat are elaborated, not already known ones reproduced), as well as the possibility of obtaining new information which can form a basis for practical recommendations. Exercises and actual combat actions without meeting these conditions are viewed as processes which exist independent of one another. This must be considered in describing game models.

Game simulation as a method of cognition of military phenomena applies to the period of initial controlled engagements. The commander has almost always elaborated his decision on the basis of analysis of presumed actions by the opposing sides. In wars of the past, when arms, tactics and organization of troops were comparatively simple, the correctness of a decision would be determined by the commander's talent and experience. As the complexity and scale of combat increased, scientific forecasting and calculations were required.

The principle of game modeling consists in the following: the executor, performing the role of umpire at each stage of the engagement, compares the decisions of the opposing sides and determines the potential result of their actions. Depending on the selected effectiveness criterion, he considers the actions of each fire unit or averages the results by tactical subunits.

Usually variants of an engagement or attack are played out move by move. Move is defined as the advance of an aircraft (group of aircraft) to each subsequent line. The number of lines specified by the executing individual determines the accuracy of the model and the duration of the process of investigation. The "adversary" undertakes a response move to each move taken by the other side. The main distinctive feature of a game model is vigorous actions by the "enemy" in a manner characteristic of him.

There exist several kinds of game modeling: mental (logical), physical, semi-physical, and mathematical.

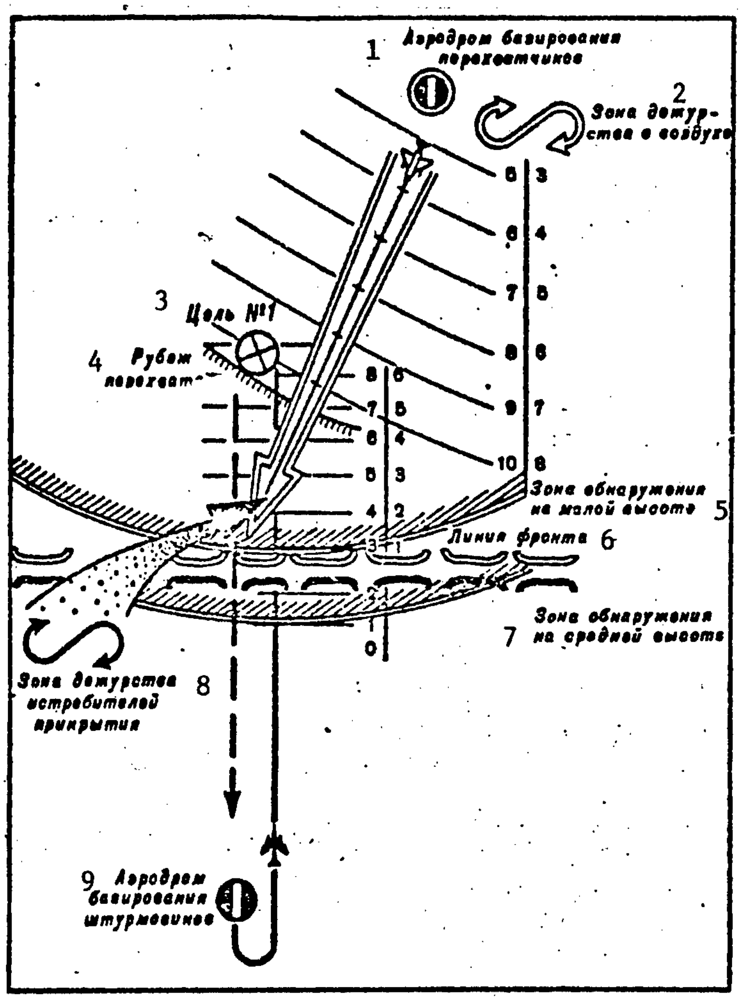
With mental modeling the commander pictures the forthcoming engagement, studies it or performs a mental experiment, after which he transfers results to the actual object. The "opponent's" plan is revealed in the course of such simulation, as well as the layout of his combat formation and modes of conduct of defense (attack), after which the structural plan of action is elaborated. Object models are usually employed in the process of mental modeling of an air engagement or attack -- models of aircraft, targets or overflown terrain as component parts in experiments (methods of mental and physical description of a phenomenon are unified into a single whole).

Physical modeling is an experiment in the air with active countermeasures by a concrete "adversary." Thrice Hero of the Soviet Union Col Gen Avn I. N. Kozhedub writes about such an experiment in his book "Vernost' Otchizne"[Loyalty to the Homeland]. This was a demonstration air engagement between a Soviet Yak with a captured Messerschmitt, a battle in which "the strong and weak points of the aircraft were studied." On the basis of the results of this full-scale simulation, recommendations were given to combat pilots on tactics of combat against specific enemy aircraft.

According to information contained in foreign publications, at the present time the U.S. Air Force has established a squadron of F-106 aircraft which "play" the "enemy." The pilots employ tactics characteristic (in the opinion of their superiors) "of contemporary air warfare." New techniques of action against the "enemy" are recorded and subsequently incorporated into pilot air combat training programs. The actions of North Vietnamese fighters in the recent war in Southeast Asia form the basis of the techniques employed by the pilots of the F-106 squadron.

Semi-fullscale simulation is conducted on ground models, which usually include a fully-functioning aircraft cockpit, a target flight (movement) simulator, and analog-digital computer and a control console for the instructor. An image of the maneuvering air or moving ground target is

projected onto screens situated forward of the cockpit. Elaboration (investigation) of the elements of air combat is performed with two operating cockpit simulators.



Graphic Display of Situation for Game Simulation.

Key to diagram: 1 -- interceptor air base; 2 -- duty zone in air; 3 -- target No 1; 4 -- interception line; 5 -- detection zone at low altitude; 6 -- battle line; 7 -- detection zone at medium altitude; 8 -- duty zone of covering fighters; 9 -- attackers' air base

Due to the high cost, semiphysical models are employed primarily for the conduct of studies connected with developing new equipment or comparing it with analogous models possessed by the potential adversary.

Mathematical simulation is an expression of the process of combat in the form of systems of equations. The stages of mathematical combat are played out on a computer (the process is called dynamic programming).

Symbol or graphic models can be called, with certain allowances, a representation on paper of the process or results of mental game simulation. Mental and logical-mathematical modeling is becoming quite widespread today in practical flight activities. However, one cannot say that there has been no experience in this area. Analysis of a forthcoming engagement, reflecting the logical process of pilot thinking, was conducted during the Great Patriotic War. The following was stated by Hero of the Soviet Union Maj P. Peskov in an article entitled "The Commander in Combat," published in the newspaper STALINSKIY SOKOL [Stalin Falcon] on 16 April 1943: "The Group commander should do the bulk of combat control work prior to departure. It is necessary to prepare for air combat on the ground. At the moment one is swiftly closing with the adversary, a commander cannot give protracted thought to his tactics and explain it to his men. He has only a few seconds to make his decision and issue orders to his group. Control in combat is complicated by the fact that the commander himself is fighting; it is also complicated by the great space involved, making it impossible to observe all details of the air engagement. Therefore it is necessary thoroughly to cover the enemy's tactics with one's group on the ground, the possible variants which the enemy will employ, all possible instances and circumstances, and to prepare several schemes, so that the pilot will know how to fight under various conditions and what the commander expects of him in combat."

The objective of game simulation is to obtain as much material as possible on the character and probable result of forthcoming combat operations. The tasks of investigation are examined somewhat more broadly than when constructing a flight model. The operating procedure of the executing personnel can be presented as follows: information stage, selection of criteria, graphic presentation of the situation and its analysis, playing out the engagement stage by stage, and selection of the optimal solution.

We shall examine the process of game simulation with a concrete example. We shall state at the outset that the proposed method is not the only one; it merely reflects certain experience in this area.

We shall designate the opposing sides "Brown" and "Blue." The "Brown" consists of subunits of ground-attack aircraft and fighter cover, and the "Blue" -- an interceptor subunit. The mission of the ground-attack aircraft is to attack target No 1, the mission of the covering fighters -- to fight off attacks by "hostile" aircraft, while the mission of the interceptors is to prevent the strike by the ground-attack aircraft. We shall emphasize one of the fundamental conditions of the study: executing personnel (the working group) takes a strictly neutral position in regard to the "adversaries." Only with an objective assessment of the capabilities of the opposing sides can one hope for reliability in a game model.

The information stage proceeds as follows. First known data on the "adversaries" are systematized: basing, composition, degree of preparedness, principles of tactical employment, and combat characteristics. Then an appraisal is made of the external conditions which will be introduced into the model: weather, topography, time of day, navigation situation.

One should bear in mind that a ground-attack mission can be modeled only with the availability of data on the "enemy" air defense system which they must penetrate. It is essential that this information be valid at the time of the strike. Thus the information needed for simulation should include data on the combat capabilities of the opposing sides, characteristics of external conditions, and intelligence on the "adversary" on a real-time basis.

Effectiveness criteria are then selected. At this stage one defines the concrete investigation aims and methods of achieving them. The greater the number of objectives, the more complex the process of simulation and the less reliable its result. It is always better to reflect in a model the most important aspects and relationships of the target phenomenon. If ground-attack aircraft have been assigned the mission of destroying a ground installation and to avoid sustaining losses, one criterion (destroying the target, for example) is taken as the main criterion in calculations. In our case, for simplicity of presentation, we shall not introduce the criterion of damage. The main task for the "Brown" is to penetrate through to the target and to avoid taking losses, while the main task for the "Blue" is to intercept them at the specified line.

As a result of modeling, we should obtain a graphic picture of the attack mission, suitable for our study. Investigation results form the basis of the decision by the commander of the "Brown." Also assisting the executing personnel are reference and auxiliary materials available in the tactical classroom. Calculations are performed on the basis of simple formulas.

At the following stage the situation is graphically depicted. Executing personnel places on a clean sheet of paper, at the selected scale of distances, airfields and air duty zones, the battle line, the "Blue" automatic radar tracking and detection zones, air defense weapon killing zones, and intercept lines for various degrees of readiness.

Based on the problem solving conditions, the "Blue" interceptors are on the ground on an alert status or scramble to their assigned area when the alert is sounded. A line indicating their possible track is run from the field and zone to the intercept point, broken down into one-minute segments. The count includes passive time expended on takeoff, climbout and turn to the target intercept course.

The flight path of the attacking "Brown" aircraft is plotted using the above-described method. It is divided into one-minute segments from the "Blue" radar detection line to crossing of that line on the return flight.

The situation analysis shows that the attacking aircraft can deliver the strike in the sixth minute (see figure) after entering the "Blue" radar detection zone when flying at low altitude, and in the eighth minute when flying at medium altitude (in this instance the detection line is closer to the airfield of the attacking aircraft, and additional time is expended on maneuver).

The "Blue" interceptors appear at the point of potential intercept in the 10th minute after takeoff and in the 8th minute after departure from the airborne alert zone. Consequently the attacking aircraft can avoid encountering "hostile" interceptors prior to reaching the target only if they employ the "low-altitude" variant.

The stage-by-stage game is conducted further. A game of chess can serve as an analog to the playing out of possible actions by the opposing sides. It is sufficient to determine what each of the opponents is thinking before each move. In our case each move is movement by the "adversaries" along the next minute segment. The game result indicates that if the "Blue" interceptors are late in engaging at the calculated point but do not decide not to pursue the attacking aircraft, the encounter may occur above the battle line. This circumstance is the principal one for selection of tactics for the "Blue" covering fighters.

The "Brown" decision. The attacking aircraft fly to the target at low altitude and attack without preliminary maneuver. There is no time for additional maneuver over the target. At the moment the attacking aircraft enter "hostile" territory, the covering fighters take position in a zone situated by the "Blue" radar detection line. The situation does not require direct escort to the target area. Is this variant optimal? The model must answer this question. The model can be interrogated with questions pertaining to solving the problem based on selected criteria: what is the mutual positioning of "Brown" and "Blue" aircraft at the present moment? What will happen if the "Brown" is delayed or the "adversary" proves to be more mobile than had been assumed? What influence on the situation will be exerted by displacement of the air duty zones of the "Brown" fighters or "Blue" interceptors? Under what circumstances is direct escort of the attacking aircraft or clearing of airspace (establishment of a screen in the target area) necessary?

Thus at this stage one can examine the properties of the target phenomenon on a model, imposing certain restrictions. We emphasize that the decision was made by the "Brown" on the basis of the results of physical simulation. It differs from solutions, which in operations research are defined as quantitative assessments obtained as a result of analysis of mathematical models. The effectiveness of simulation (using a simplified method) is evaluated on the basis of how it assists the commander and pilot in selecting an optimal action variant, whether it is accessible in a realistic working situation, and whether the adopted solution is optimal according to the basic parameters. (To be continued)

Similar Analog Model

Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 6, Jun 77 signed to press 29 Apr 77 pp 16-18

[Article by Cols V. Babich, A. Dubovitskiy, and Ye. Lavrent'yev: "Analysis, Playthrough, Plan"]

[Text] Under all conditions it is believed that elaboration of a physical analog is a first and mandatory stage in simulating a flight mission. One

can construct a mathematical model only after selection and formulation of the physical characteristics of the object, that is, examination (discussion) of a physical model. In this article we shall examine the example of construction of a model by a similar analog, as well as the indicators of reliability (realisticness) of a model, and some rules of examination with this method.

The composition of forces and combat capabilities of the adversary have not changed: the "Brown" force has ground-level attack aircraft and fighters, while the "Blue" has interceptors. The "Brown" has been given a new mission. Its fighters are to challenge the "Blue" interceptors to combat and inflict the heaviest possible losses in the air.

Inasmuch as the "Brown" side already possesses some experience in modeling, we can include a point on analog selection in the information stage. In other words it has become possible to seek a ready model which corresponds to the situation and which has undergone practical testing.

The criteria on the basis of which optimization is performed will be an attack against hostile aircraft, with the element of surprise, and no friendly losses. The first criterion is the principal one.

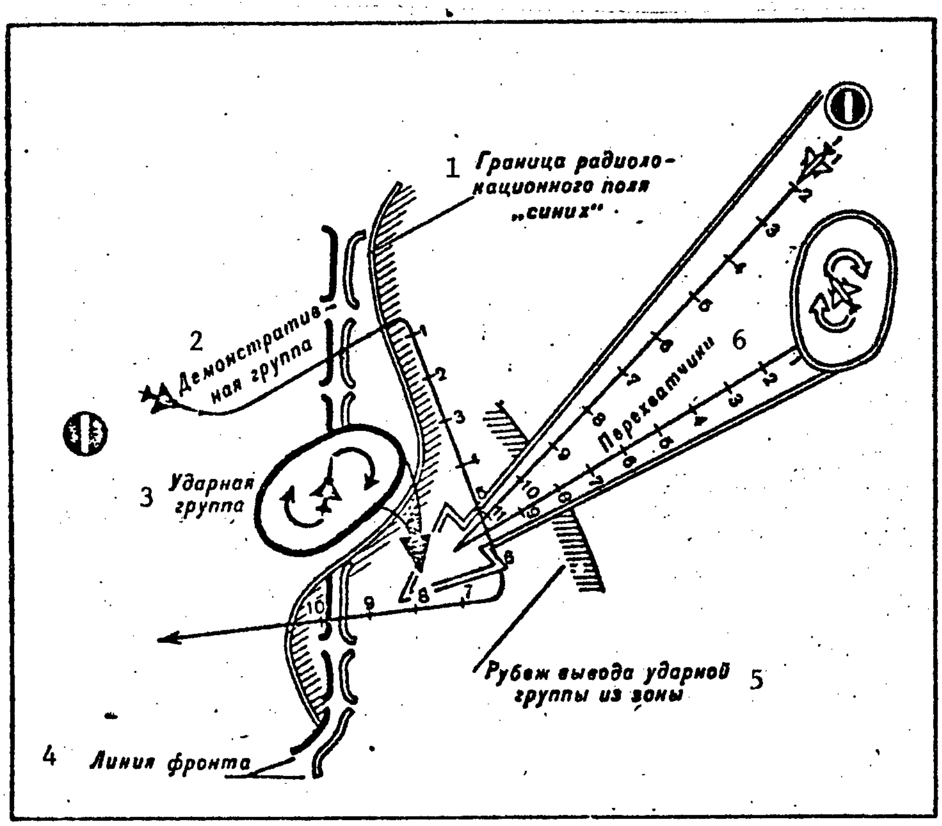
At the information stage the executing individual comes to the conclusion that he can take as a basis of examination an attack model elaborated previously (see article "Searching for a Better Variant," AVIATSIYA I KOSMONAVTIKA, No 4, 1977). Since the attacking aircraft successfully mounted the strike and were not attacked by enemy interceptors, they can be assigned the role of diversionary group. The cover fighters become the attack group. The roles are changed, but not the sequence of mission execution. This means (to certain limits) that the previously-performed calculations are also valid.

The basic plan is to scramble the "Blue" interceptors against the diversionary group, drawing them off in pursuit into a designated area, subsequently mounting a surprise attack from beyond the "enemy" radar-covered area.

In order to ensure the safety of the ground-attack aircraft, their depth of penetration into enemy airspace can be reduced. The time safety factor excluding a confrontation with the "Blue" interceptors is determined as a result of playing out the variants stage by stage. Following graphic situation display and determination of gaps in the "enemy" radar observation zone, the location of the air ambush is selected. A line is designated, after crossing of which by the "Blue" interceptors the "Brown" fighters are engaged. Information on crossing of the line comes by radio from a ground control facility or from the leader of the diversionary group.

The playout of the variants gives reason to assume that if events develop according to the "Brown" plan, the "enemy" interceptors will enter the

ambush and will be attacked with the element of surprise. The fighters will enter deliberate combat, which will begin with a specified arrangement of forces in the air. The situation will make it possible to dictate terms to the "adversary" and will ensure seizure of the initiative. Achievement of success should also be promoted by a programmed element of surprise. The "Brown" decision is based on an optimal engagement variant selected in the course of playing out the mission (see figure). The plan specifies when the count begins, the procedure of control and maintenance of continuous coordinated action between the diversionary and attack groups. When necessary a reserve is designated (a group to build up the attack effort).



Graphic Situation Portrayal for Playing Out Deliberate Engagement of Fighter Attack Group

Key to diagram: 1 -- boundary of "Blue" radar-covered area; 2 -- diversionary group; 3 -- attack group; 4 -- battle line; 5 -- line of withdrawal of attack group from zone; 6 -- interceptors

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A ready model taken from the library suggested the employment of a new device. Examination was significantly facilitated thereby, by shifting certain details. The attack model proved useful in elaborating a model of engagement. If conditions were changed, however, such as a ground target displaced deeper into enemy territory, the attack model would be of a

An inaccuracy can be revealed, for example, in the following determination of target: "Execute a decoy (feinting) maneuver." In actual fact this is not one but two maneuvers, different in content. In tactics a "decoy" is an attempt to compel the adversary to concentrate his forces on a phony axis of attack. A feinting or diversionary maneuver is performed with the objective merely of diverting the adversary's attention from the selected direction of attack. A similar lack of clarity arises with the following specification: "Breach (surmount) target objective air defense." "Breach," states the dictionary of military terminology, is a vigorous, decisive mode of penetrating a deeply-echeloned enemy defense, breaking through it with the aim of subsequently putting the main forces into the resulting breach. Surmount is a more general term which, in addition to such methods as breaching, also includes bypassing lethal areas, undetected "infiltration" by aircraft deep into enemy territory and evasion of antiaircraft fire. In the one instance the method is based on fire neutralization, and in the other -- preservation of invulnerability, concealment to gain the element of offensive surprise.

Thus to model penetration or bypassing of a danger area is not one and the same thing. In like measure, uncertainty can be introduced (directing modeling along an incorrect path), such as excessively general determination of the objective, and imprecise use of tactical terminology.

We shall now discuss adequacy of information. Cybernetics provides a precise (for modeling) definition of information: "Information is all that which eliminates uncertainty." Analyzing available information, the executing individual should observe the principle of adequacy. Depending on the quantity (completeness) of data, information contains more greater or smaller details on the air situation, but cannot be its absolute expression. An all-encompassing situation picture is not required for modeling concrete tactical devices. The degree of detailing should correspond to the conditions of mission execution. Consideration of unnecessary or secondary factors will only complicate the process of modeling and will not affect the end result.

Also of considerable significance is the adopted level of synthesis. In analyzing a weather report, for example, instability of the weather requires that it be averaged. The same can be said about the expected intensity of jamming, or uninterrupted control from the ground. In selecting a mode of action, preference is given to objective information based on facts.

Processing of available input data can be broken down into three stages: analysis of suitability of information for solving the specific problem, synthesis of secondary data and detailing of requisite data for simulation. The executing individual should be convinced of the adequacy of the necessary data and should obtain lacking data. A list of required initial materials and information sources for constructing standard models can order and simplify this process.

And now a few words on utilization of information models. This signifies that one should do less calculating and take more information from graphs

totally different form and could not assist the executing individual. Thus it is once again confirmed that simulation is always based on experience but requires constant innovation.

What is the reliability of a game model? The correctness of conclusions obtained as a result of examination of game models depends on the completeness and genuineness of data on the adversary. One of the fundamental rules of game modeling is consideration first and foremost of the opponent's strong points, followed by search for weak points. The skill of the executing individual consists in revealing the opponent's concept, his possible plan of action, not forcing him to make moves advantageous to his opponent. To construct a game model of the chess game type means to suffer failure in advance. The opponent is a grand master who will not be inclined to repeat the moves of the game he played on the previous day.

It is also necessary to note that game models make it possible to transfer to an actual object (any tactical device at two-sided exercises) far from all conclusions, since they do not fully reflect the complexity of the forthcoming events. Of the greatest value are results pertaining to specific, precisely formulated tasks, such as one-on-one (and sometimes group) air combat with a specific opponent or an attack on a ground installation the antiaircraft defense system of which is known in advance.

In the process of modeling it is desirable to observe certain rules, which can be formulated as follows: clarity of the problem, concreteness of the objective, adequacy of information, utilization of information models, prevention of repetitions.

Let us examine each of these in greater detail. We shall begin with the first -- clarity of the problem. The tactical problem should be stated to commanders in such a manner that not much time is required to think it over, but they can immediately proceed to examine the problem. Brevity and preciseness of the assignment determines correct selection of an analog and auxiliary material for calculations. In addition, conditions are created for balanced logical deliberations (construction of a mental model). Lack of clarity at the outset of the modeling process can involve first and foremost ignorance by the executing individual of the composition of forces involved in performing the air mission, and the situation at the beginning of combat operations. The mission, worded approximately in the form "destroy the enemy, fighting bravely and resolutely," cannot serve as a basis for construction of a game model.

Concreteness of objective is also essential. Precise determination of the concept and objective of the engagement (attack) determines the completeness and correctness of conclusions (results of modeling). The executing individual should have a clear picture of what is to be achieved with employment of the variant he is elaborating. For example, penetrate to the objective without detection, attack as quickly as possible, seal off the airfield, construct an efficient combat formation, etc. Streamlined formulas are inadmissible here, and inaccuracies are dangerous.

and nomograms. It is true that this principle requires an adequate quantity of requisite materials. They should be simple to use, such as the navigator's plotter, where bank radius and time are determined in seconds. Considerable possibilities for combat simulation will be found if the same method is used to determine the level of energy based on known magnitudes of its components (or other data influencing the attainment of tactical superiority). At first it is not mandatory to count meters, seconds and degrees. It is sufficient to determine "larger" or "smaller" in a comparison in order to determine a standard of behavior in combat.

Standard models calculated with the aid of a computer, which are used as a model in calculations, can be useful. At one time intercept models constituted a reliable basis in forming new techniques. As is indicated by the experience of local wars, many types of antimissile maneuver -- S-turn, alternate passing, fanning out -- were elaborated on the basis of similar maneuvers against antiaircraft artillery, employed in the era of piston aircraft.

Finally, elimination of repetitions. This principle presumes possession and practical utilization in practical modeling of air-tested models of engagements or separate tactical devices. It is necessary to commit to memory not only successful but also unsuccessful devices. The following question immediately arises: there are very many devices, and an entire library will be required to store them. An answer can be provided by anybody who attempts to weigh his tactical baggage and inventory it. A perusal of a library of models will not always permit selection of a complete analog, but one can copy individual elements. In addition, the way is opened up to study modern tactics and to establish new and effective devices.

A successful device is usually repeated until it ends its usefulness. Failure serves as a warning for the future.

The Americans in Vietnam, for example, installed new low-power jamming transmitters on board their tactical aircraft and constructed a model of a close-packed combat formation. They were counting on effectively protecting their aircraft with active jamming. As a result some antiaircraft missiles missed, but those which did hit the target brought two aircraft down at once. The technique was discarded, and intervals and spacings between aircraft were once again increased.

According to reports in U.S. publications, it has also been necessary to abandon the so-called "sudden appearance" method, which was played out on numerous occasions under practice area conditions and promised a high degree of invulnerability to the attacking aircraft. It consisted essentially in the following: the attacking aircraft would approach at treetop level to the inner boundary of the antiaircraft system killing zone, upon which it would execute a steep vertical bomb delivery maneuver -- "an over-the-shoulder turn." That airspace not covered by missile fire, however, proved to be covered by antiaircraft artillery. An aircraft which did not

rapidly change its angular position relative to the battery would come under fire. This variant was not considered in the process of modeling, and as a result the model was kept in storage in order to avoid repeating it.

Some models of combat maneuvers in local wars have not been given unequivocal assessment, although they have passed the test of fire. This applies to the deliberate separation of flight leader and wingman in a two-aircraft flight in the process of maneuver combat. Standard and tested maneuvers under the names "defensive split," "hard turn," "scissors" and others have produced the anticipated result only with planned actions by the adversary. If the adversary's response maneuver or countermaneuver was illogical, a so-called critical situation would develop. Analysis of such situations indicated deficiencies in the equipment (aircraft) or poor training of the pilot.

One example of a technique elaborated by methods of mathematical and physical modeling is a maneuver to evade a surface-to-air missile which was utilized by U.S. pilots in the air war in Vietnam. Initially the converging flight paths of aircraft and missile would be calculated mathematically, after which evasion variants were practically tested (physical model). There were three principal variants: a vigorous turn toward the missile with a subsequent dive or pitchup, a rollout, and carrythrough beyond the potential attack target. According to calculations, the optimal distance at which to initiate the turn was 5-7 km.

Experience indicates that the "situation analysis at 1300" method is unsuited for modeling combat. The search for optimal variants involves creating mobile situations in a limited airspace. The attack is simulated above a model of the practice range or target location area, and examination with a graphic analog -- marked-out flight paths, is effected by moving the pencil by minute segments, making intermediate decisions. The logic of the forthcoming combat is born is movement, in a dynamic situation, the direction of the main attack is chosen, and each maneuver is substantiated. It is difficult to write all this down on paper, particularly in mathematical form, but it can be constructed. The pilot can be assisted in this by simple simulation methods.

The main advantage of game modeling in our opinion is elucidation of the most effective technique and mode of action with a specific disposition of enemy forces, the possibility of predicting the result of an engagement (attack), as well as determination, on the basis of comparison of the anticipated attained result, of ways to achieve further improvement of tactics. (To be continued)

Mathematical Logic Method

Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 7, Jul 77 signed to press 31 May 77 pp 10-11

[Article by Cols V. Babich and A. Dubovitskiy: "Logical-Mathematical Method"]

[Text] This article deals with the possibilities of the mathematical logic method in simulating air combat. We shall examine two items: the requisite level of training of the executing individual, and the stages and result of modeling.

In order to obtain positive results it is necessary to employ the data of combat experience, knowledge of one's weapon and the ability to master it, and also to take into consideration the combat capabilities and tactics of the "opponent." Of importance thereby is the ability to analyze and to think logically. It is essential in view of the limited nature of input data for calculating quantitative characteristics (probability of intercepting, downing the adversary, etc) in preparaing for a mission.

As is indicated by past experience, each generation of fighters has left behind a generalized model of air combat, which comprised the basis for examination in forming new tactics applied to new aircraft. The experience of the Great Patriotic War is particularly valuable under present-day conditions. The traditions of the glorious Soviet aces are grounded in the principles of contemporary air combat, demands on combat formations, methods of achieving tactical superiority in combat, and the moral-political training of pilots.

Aggressive character, close coordination between aircrews (groups), the element of surprise, a skillful combination of maneuver and fire, intelligent operation of one's aircraft, initiative and constant improvement of tactical devices were considered basic principles of air combat in the last war.

The following demands were made on a combat formation of fighters: freedom of maneuver, securement of 360° search, mutual fire support, capability of rapid re-formation, concentration of efforts on the axis of attack, precise and continuous control, maximum concealment.

"Altitude-speed-maneuver-fire" is the well-known formula for combat by A. I. Pokryshkin. It pointed out ways to attain victory and could be considered a unique and expressive model, on the basis of which concrete plans of an offensive air engagement were put together. The plans proper were born in the course of running through the mission on the ground and constituted detailed optimal variants of forthcoming actions in the air. A book entitled "Taktika istrebitel'noy aviatsii" [Fighter Aviation Tactics], written just after the war on the basis of an analysis of combat experience, stated: "Following are the basic elements of the plan: the combat objective (resolute annihilation of the adversary or stopping of an enemy

attack), the combat concept, the methods by which tactical superiority over the adversary is achieved, distribution of forces by stages of combat (change in combat formation), principal direction of attack, methods of control and coordinated action. The combat plan, in the form of a presumable variant (sometimes several variants), is elaborated on the ground, refined in the air after obtaining initial data on the adversary, and is finally adopted when the fighters spot hostile aircraft en route. Necessary changes, which are dictated by the situation, can be introduced into the plan when closing with them, and also during combat."

War veterans claim that experienced commanders, studying the situation, would create a mental picture of the forthcoming engagement and specify the surest ways to accomplish the assigned mission. Pilots who carefully prepared for each mission also approached this level. Supported by their knowledge of combat experience, they would draw an analogy with an engagement which had taken place in a similar situation and would use it as a model. It was taken into consideration thereby that there was never a total similarity and that the new engagement would have its own unique features. Therefore the analogy method proper was never confused with mental processes or conclusions based on them. The ability to select the most suitable variant from a number of known variants was considered a valuable quality, which created conditions for making an optimal decision.

It is appropriate in this connection to quote from the book "Istrebitel'naya aviatsiya v Otechestvennoy voyne" [Fighter Aviation in the Patriotic War]. It states: "A most important condition for successful combat and achievement of close coordination was study on the ground of different attack variants which determine in advance pilot actions, such as when encountering a single reconnaissance aircraft, a group of bombers, a pair of fighters approaching high or low at various angles, etc. All new variants would be elaborated in conformity with enemy aircraft types and the concrete situation conditions. Prior preparation with this method enabled the pilot quickly to reach the most correct decision in combat."

This method was then called "advance preparation for combat." Today it would be called modeling. We shall note that this method of preparation was actively employed at the front under conditions of an acute shortage of time and without computers.

Referring to the experience of the Great Patriotic War helped find answers to questions about the objective, methods and results of modeling air combat. Objective: quickly reach the most correct decisions in combat. Methods: elaboration of an optimal variant (several variants) in the course of running through the mission on the ground. Results (simulation output): plan of the forthcoming engagement.

Combat modeling includes all stages of construction of a game model. At the information stage the pilot selects from the entire set of available and incoming information on the adversary the input data requisite for modeling. He should not experience a shortage of information, for in the final analysis

information will determine the realisticness of the model. At the same time inclusion of a large quantity of data in the process will only make the study more difficult and will not appreciably influence the result. For example, in modeling close combat it will definitely be necessary to have performance data on weapons, aircraft power and maneuverability, while an intercept model cannot be prepared without speed and altitude data. Essential for other types of combat are other but always concrete and sparse data.

The following factors, which directly affect the course and outcome of air combat, must be considered: pilot, aircraft, armament, electronics, control system. They are often called "components of success," alongside the correlation of forces of the opposing sides. Experience indicated that if one side achieved superiority in all components, it could be considered the probable victor even before combat was joined (if the morale factor and random occurrences were ignored). This meant that pilots had greater fire and tactical capability, aircraft with better performance and equipment, making it possible to detect and lock onto the target at greater range. In addition, a flawlessly-operating warning system would beat the adversary in providing information to friendly fighters on the air situation.

With these advantages the adversary could achieve success only by achieving total surprise or by employing a new tactical device against which effective countermeasures had not been developed. We must note that superiority was rarely observed in all specified indices in large-scale conflicts. In the Great Patriotic War air engagements (at least the majority) were waged by fighter aircraft of approximately the same type but with differing performance characteristics (the Yak-3 and the Me-109, for example). The same can be said about the wars in Korea, Indochina, the Near East, where air combat involved either subsonic jet or supersonic fighters with approximately the same armament and equipment. A dissimilarity could be determined only with a precise comparison of detection range of on-board radars, killing radius and pilot capability. Comparison would sometimes take place in the air in the process of experimentation or, as it is now called, full-scale physical modeling.

In 1942, for example, the Scientific Research Institute of the Air Force conducted an experiment with the participation of a Soviet Yak-1 fighter and a captured Me-109. A series of test air engagements were conducted, the objective of which was to determine effective maneuvers based on revealed weak points of the enemy aircraft. The results of the experiment, in the form of recommendations on tactics of combat with the Messerschmitt, were sent out to all active units. Optimal variants were put together in conformity with the recommendations, on the basis of which the plan of a forthcoming engagement would be elaborated.

In proceeding with modeling, the pilot usually had results of comparison and recommendations on combat with a concrete adversary. In addition, methods manuals always contained models of standard attacks, defensive maneuvers and tactics. In most cases the pilot had to put together a

combination of these or select a variant corresponding to the situation. However, there was constant search for new innovations, since in time the enemy would determine the secrets of our tactics and would himself attempt to avoid predictable repetition. Equipment and weapons were upgraded in the course of the war, and old methods of combat employment would prove unsuitable.

Considerations of logic were essential in the course of running through an engagement in advance, and in determining each sequential move by the adversary. Here the pilot had to be able skillfully to utilize available comparison data and to perform the requisite calculations in order to draw correct conclusions. Logic was combined with mathematics. In other words, it was necessary in combat fully to utilize one's strong points and to conceal weaknesses from the adversary.

The experience of past wars (including recent conflicts) indicates that most frequently the adversaries had different altitude capabilities as well as differences in power and maneuverability, with other indices approximately equal. Superiority in thrust to weight was characterized by a great surplus of thrust, making it possible to climb faster. Better maneuverability was achieved by lower wing loading and provided considerable horizontal trajectory curvature.

Following is an excerpt from recommendations on utilization of fighters in combat against fascist aircraft (distributed to all regiments during the Great Patriotic War). "4. A comparison of the specifications and performance of our new aircraft with the Me-109 shows the following: a) the armament on our aircraft is more powerful; b) our Yak-1 has greater speed, equal rate of climb and better horizontal maneuver capability at altitudes above 3,000 meters. At lower altitudes the Me-109 has superior maneuverability and rate of climb." Also contained were data on climb during a combat turn and altitude loss during a roll, bank time and radius, times various altitudes are reached, armament specifications and most advantageous maneuvers.

The pilot needed precisely such information on the enemy (rather than weight, dimensions, type of powerplant, etc) for a comparative analysis and elaboration of combat tactics. It was recommended "that the adversary be drawn to a disadvantageous altitude by a combat formation echelonment in which the group engages, while the covering group continuously attacks the adversary vertically. It would be a gross error to transition to horizontal maneuvering immediately following the first pass. The initial altitude advantage should be maintained during the entire engagement and be expended very economically."

It is characteristic that approximately the same situation developed in air combat in Korea between the MiG-15, flown by pilots of the Democratic People's Republic of Korea, and American Saber jets (Fokhter: "Vozdushnyye voyny" [Air Wars], Moscow, Voyenizdat, 1957). As was noted in foreign publications, in the war in Indochina North Vietnamese pilots developed their tactics taking into account the excellent maneuverability of their

aircraft (lower wing loading with equal thrust to weight) and better high-altitude performance characteristics. A comparison of the numerical composition of the sides participating in combat (the adversary had considerably more aircraft) indicated the necessity of selecting in tactics the principles of surprise and economical expenditure of forces. Attacks were to be delivered at the enemy's most vulnerable spot. Taken into consideration thereby were not only the vulnerable points on the aircraft and weaknesses of the weapons, but also deficiencies in ground control, the rigidness of the combat formation and the poor psychological preparation of aircrews.

We must also discuss another matter. In order to model air combat, essentially a highly complex phenomenon, it was necessary to know the laws and patterns of its development and to take into consideration new conditions and factors influencing choice of tactics. An analysis indicates that the role of the principal elements of combat -- maneuver and fire -- gradually changed. Maneuver occupied an increasingly subordinated status in relation to fire and was considered merely a technique supporting initiation of the attack. With the appearance of air-to-air missiles as fighter armament, the term "strike" began to be adopted -- a combination of fire with forward movement by one of the groups of aircraft or the entire combat formation. In constructing his model the executing individual took into consideration that the main element in the strike is the moment it is delivered and the direction of the salvo. The strike or attack usually determined the outcome of the engagement, and therefore it was painstakingly planned (played through) and supported with auxiliary forces.

Combat formations began to detach as aircraft became faster and more potent. The squadron commander received certain independence in performing tactical missions, as did subsequently the flight leader and, finally, the leader of a two-aircraft flight. This means that an increasingly broad group of flight personnel are being involved in modeling combat. Practically every pilot elaborates a mission plan, where the "adversary" will be encountered, on the basis of an optimal variant selected from several possible variants.

The space occupied by combat is also steadily increasing. This limits the group commander in monitoring the actions of his men but does not eliminate continuity in controlling them. A ground command post is exerting increasing influence on the course and outcome of air combat. For example, not only pilots but also the control facility team took part in combat in Vietnam and in the Near East; the control facility team monitored the air situation by radar and informed the pilots of situation changes. Frequently the command post would determine the moment and direction of attack. Thus there was an increase in the number of elements which had to be considered and compared in the modeling process.

Laws and patterns of development of combat also include a steady increase in the pace of combat and succession of events. Less and less time is available for thinking through the next move, but the mental process proper is not diminished. It is transferred to the ground, to the classroom,

where in a calm environment the pilot can solve many tactical problems and choose optimal variants for various conditions.

Thus the comparative analysis performed at the initial stage of modeling can be called a process of information-calculation and logical-analytical (creative) activity on the part of the pilot (commander). The content of and conclusion from the analysis would be organically incorporated into subsequent stages and influenced by them. (To be continued)

Air Combat Tactics

Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 8, Aug 77 signed to press 1 Jul 77 pp 20-23

[Article by Cols V. Babich and A. Dubovitskiy: "Shaping the Tactics of Combat"]

[Text] The basic content of the information stage in modeling air combat is a comparison of the forces and combat capabilities of the opposing sides, as well as estimate of the current situation. The specifics of the work performance by the executing individual at the two subsequent stages -- selection of criteria and graphic representation of the situation -- has been fairly completely presented in an article entitled "Games Method" (AVIATSIYA I KOSMONAVTIKA, No 5, 1977). We shall now discuss stage-by-stage playing through the engagement and selection of an optimal solution.

It is expedient to play out a mission stage by stage as follows. Dividing the entire engagement into stages, the executing individual determines what the main element at each stage is, and then in the process of closing movement by the opponents, move by move, he selects the method of achieving the intermediate and end objectives of the engagement.

Approach has always been considered the first stage of any air engagement. The main thing on the approach is establishment of conditions for an attack with the element of surprise. This is confirmed by the experience of the Great Patriotic War, where three fourths of all enemy aircraft shot down in combat were hit on the first pass. The element of surprise was a result of the highly-developed tactical thinking of the pilot (commander) and was achieved by skillful utilization of such factors as concealment, observance of concealment measures, military cunning, and constant renewal of the techniques and methods of combat. An unexpected attack frequently stunned the adversary, made him unable to offer vigorous resistance, and decided the outcome of the battle at the first stage. Frequently success was achieved with enemy numerical superiority in the air. Even under present-day conditions this was graphically demonstrated by North Vietnamese pilots in the war in Indochina, who won victory in air battles against a numerically superior adversary.

The search for ways to gain the element of surprise would be carried out in the course of detailed assessment of the air situation long before combat was joined (i n our case at the information stage). Analysis indicated

what method (feinting maneuver, deceiving the enemy, decoy actions, etc) is most acceptable for the specifically occurring conditions. In local wars one of the adversaries at times counted solely on the element of surprise and on the result of the first pass. If it failed, the attacking aircraft would break off entirely.

When concealment was placed in doubt (for example, combat was to take place in an area with hostile radar coverage), accumulation of energy by means of a rapid speed increase was considered a most important element in the approach. At this stage the advantage was obtained by the aircraft with the better acceleration capability (a better thrust-to-weight ratio).

The level of energy can be expressed as the sum of an aircraft's potential and kinetic energy. Potential energy is directly proportional to altitude. Kinetic energy can be defined as a certain fictitious altitude which an aircraft reaches at the cost of a total loss of speed. The sum of these altitudes constitutes the level of energy which the pilot can transform into tactical advantage. The value of speed on approach can be demonstrated with the following example.

While executing a steep climb, an aircraft is able to gain 370 meters in altitude from an initial speed of 700 km/h with a loss of 10% of that speed on top. Under these same conditions an aircraft will gain 740 meters with an initial speed of 1,000 km/h, that is, twice as much. As was noted, in three cases out of four air combat ended in the first stage -- after the first successful pass. If the adversary succeeded in responding promptly and undertaking defensive measures, the maneuver stage would begin, where each of the opponents would seek to enter the mobile area of possible weapons employment. Superiority in angular speed of turn was considered the principal element at this stage. A so-called extended advantage went to the aircraft with a light wing loading, with a smaller radius and stabilized turn time. The aircraft with the greater thrust-to-weight ratio, however, could exceed the more maneuverable aircraft in transitional turning speed by extinguishing a portion of surplus energy.

Forced turns (with a high G-load and deceleration) would usually be executed to an angle of not more than 270° in order to enter the potential attack (permitted fire) area as fast as possible or to evade attack passes when the adversary was spotted at weapons employment range. Forcing conditions involved loss of energy, which subsequently was difficult to accumulate. Therefore the pilot precisely selected the moment of deceleration in order to eliminate the threat of being shot down or to reach the firing point more rapidly.

We have examined an example of the influence of advantage in speed on altitude gain capabilities. Now we shall see how speed (level of energy) influences attainment of a position advantage in the course of maneuvering (see figure on back cover).

The adversaries spotted each other simultaneously. Maintaining identical altitude and speed, they began to close. As the aircraft close on one another, the pilot of the aircraft with the higher thrust-to-weight ratio will have a higher energy level due to more rapid acceleration. However, in the process of maneuvering, he will be on the outside of the turn in relation to his adversary if he utilizes steady-state speed and G-load conditions. In order to reach the potential attack area he must get inside the turn or fall back and reduce the angle. He can achieve this only by means of deceleration and increasing the angular speed of turn; otherwise the adversary's position will be more advantageous. Here logic is bolstered by calculations.

Let us assume that at the initiation of maneuver the first aircraft has reached a speed of M=1.5, and its adversary -- only M=0.8. The pilots know that the greatest angular speed of a steady-state turn, independent of the type of aircraft, lies within the range M=0.8±0.2. Therefore the first aircraft enters this range with deceleration, and the latter without changing conditions. Possessing excess speed, the first aircraft expends it to increase the angular speed of turn (creates a G-load close to maximum, increases drag) and turns 270° by the moment it enters the range M=0.8, while the second aircraft, maintaining its speed, turns only 180°. The gain in direction change is 90°. Thus favorable conditions were created for entering the potential attack area. However, failure to utilize this situation to deliver ordnance deprives the first pilot of a position advantage in continuing maneuver. Subsequently he will be compelled once again to straighten his trajectory and expend time to accelerate to the requisite speed (if the aircraft's wing loading is greater).

Thus to the main criterion at the second stage -- advantage in angular speed of turn -- one should add intelligent expenditure of the aircraft's energy. The experience of actual combat indicates that the endeavor to enter the speed range corresponding to optimal maneuverability (M=0.8±0.2) led to a constant decrease in altitude and speed. Whoever decelerated unintelligently, endeavoring to turn faster than the adversary at an inappropriate moment, would gradually lose the capability to attack and would be compelled to defend himself.

In our example the surplus speed of one of the adversaries was sufficient to reach the boundary of the potential attack area. But at that moment energy levels were equal. What subsequent move will be most advisable for the adversary? Readers who wish to continue combat modeling may solve this problem.

At the third stage -- during the adversary's attack pass -- the main criterion can be selected in relation to type of weapon, area of its potential employment, and number of points of fire delivery on the aircraft. Evidently the pilot needs most of all accuracy and swiftness, that is, qualities acquired through persistent labor and drill.

At the fourth stage -- in the process of disengagement, the main thing is not to lose momentum, plus vigilance.

We must state that increasingly less room remains for logical deliberations in modeling the third and fourth stages. The pilot can adhere to several elaborated and well-assimilated variants. For example, cannon fire could be effective only with observance of specified rigid conditions regarding range and angle of approach. Elaboration of many methods differing from one another was not required. Some adjustments were made to this point by the experience of the war in Vietnam, where fighters employed in combat both cannon and guided missiles. Nevertheless even in Vietnam an attack could be effective only from the rear quarter and from strictly-limited ranges.

We should note that the number of stages in the air engagement was selected taking into consideration the experience of past wars. The executing individual can increase or decrease them in conformity with the assigned mission, level of training and available time. The model will not be more reliable if one increases the number of moves in the preliminary run-through, but the pilot will be prepared to respond correctly to more frequent situation changes.

Forecasting of the enemy's actions is based on the assumption that he will not be able to perform those maneuvers (devices) which are disadvantageous to him under the existing conditions. One can hardly expect that, inferior in thrust-to-weight ratio (rate of climb), he will exit from the pass with a climbing maneuver. However, an adversary's "illogical" move in the air has frequently compelled one to ponder the matter, where it was necessary to act. But it was no simple matter to go ahead with some doubtful experiment without preparation on the ground.

Arbitrarily separating logic and mathematics in our method of investigation, we shall note that logic predominates at the first stage, after which it merges with mathematics. This does not mean that the pilot will be performing complex calculations. He should skillfully utilize available reference material in order quickly to select the optimal combat maneuver type and conditions. This is discussed in a fair amount of detail in articles by Engr-Col V. Taranenko entitled "Optimal Maneuvers" (AVIATSIYA I KOSMONAVTIKA, Nos 5, 6, 7, 1977).

Establishment of the combat formation, which begins long before the approach, is eliminated from these stages. We shall note at this point that correct placement of forces prior to an engagement determined its outcome to a great extent. However, with improvement of radar means of detecting air targets, it was becoming increasingly more difficult to conceal the combat formation (and consequently to achieve the element of surprise). Figuratively speaking, the position of the adversaries prior to engagement was reminiscent of two fencers, each of whom possessed identical weapons and knew that he would be attacked, but one of them nevertheless would fail to

parry an unexpected thrust. The one more skilled in tactics would be the victor.

While in one-on-one combat flying skill and gunnery training played the principal role in achieving success, in group combat it was skillful arrangement of the combat formation and change in formation from stage to stage. In the air fighting in Vietnam and in the Near East, with open initiation, the outcome would frequently be decided by the attack run by the attacking group, while conditions for gaining the element of surprise would be provided by a diversionary maneuver by the decoy group. In the war in Korea the enemy's combat formation would be split by a dagger-thrust pass by the lead group, while the attack group would attack the enemy aircraft, which were deprived of support.

There can be many variants of arrangement of forces and change in combat formation, and selection of the optimal variant is the first step taken by the executing individual who is modeling a group air engagement. The second step is distribution of missions among groups of differing designation and determination of the sequence of their engagement. Thus move-by-move progression began not at the moment the adversary was detected but long before that, when the logic of combat had already been determined by the executing individual. Appropriate here is comparison with a chess player who begins the game with a predetermined opening. I emphasize -- only an opening, that is, the initial stage of the contest. Nobody has yet succeeded in mentally playing through an entire game alone prior to its beginning. This must be clearly understood by the individual who is proceeding to model an air engagement if he lacks a two-cockpit semifull-scale simulation complex or is not counting on one decisive attack pass.

Also indicative, however, is another example. The grand master differs from the master, and particularly from the novice not only by a more highly developed and focused mental process but also by the ability to make the first 10 moves in any situation without thinking about it, but correctly. As experience indicates, the initiative is seized most frequently at this stage.

Modeling of aerial combat ends with decision-making (or approval by the commander of an optimal variant plan). Here one should bear in mind that there have been no identical engagements, but only similar ones. Therefore there can naturally be no identical plans. The plan adopted for execution is always calculated for a concrete situation. Therefore one can limit oneself to principles and stages, without citing a solution example. However, it is possible to shape the thrust of tactics for two aircraft with dissimilar performance characteristics.

Let the first be the aircraft with a better thrust-to-weight ratio and the second -- an aircraft with a lower wing loading (better maneuverability). Experience indicates that the pilot of the first aircraft sought to gain an

advantage by adhering to the following principles: element of surprise in the first pass; the endeavor to keep the adversary at a distance ensuring rapid closing; in the dynamics of combat -- a series of passes with separation from the adversary and preference to vertical maneuver; an intelligent expenditure of energy, which is easier to accumulate in a straight line. The pilot of the second aircraft observed the following principles to achieve success: the element of surprise in the initial pass; the endeavor to enter close combat; in the dynamics of combat -- a continuous turn toward the adversary, preference to horizontal steady-state maneuver (conservation of energy).

In general one can state that the first pilot concentrated on maintaining distance in the engagement, and therefore he could adhere to the tactics of "series of passes" (advantage at the first stage). The second pilot concentrated on maneuver after engagement in close combat (advantage at the second stage). In group combat and with an unequal correlation of forces, these principles were retained for the most part.

Thus modeling, which performs the role of binding element between theory and practice, constitutes one of the effective methods of investigation of air combat. The closest to actual combat is a physical model, experimentation in the air. But this is not always possible. Any other analog does not sufficiently fully reflect all properties of combat between aircraft in the air, and therefore the results of the investigation are considered approximate. At the same time the simplest game models, which have their place in practical flight operations, have some things in common with actual combat in principles of structure and functioning. This positive property of models is utilized for seeking optimal solutions in concrete situations.

Definition of Model

Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 7, Jul 77 signed to press 31 May 77 pp 12-13

[Article by Lt Col A. Yena, Military Pilot 1st Class: "What Is a Model?"]

[Text] I read with interest the article entitled "From Copying to Originality" (AVIATSIYA I KOSMONAVTIKA, No 3, 1977). The authors raise the important question of innovative approach to preparing aircrews for missions on the basis of modeling methods.

The word "model" has firmly entered our lexicon, particularly in recent years. Experience shows that today it is impossible effectively to realize the combat capabilities contained in third-generation aircraft without thorough calculation of a mission and without a thorough analysis of its model.

When speaking of mission modeling, however, one should have a clearer concept of the meaning of the word "model." Let us turn to the S. I. Ozhegov Dictionary of the Russian Language. It states that a model "is a smaller (or full size) reproduction or scheme of anything. Ship model. Flying model of an airplane." And modeling is first and foremost the process of building a model, followed by examination of the model. Examination is an analysis of a flight mission model, as a result of which we select the optimal variant for the actual flight.

From this it becomes clear that in the process of constructing the model it is only partly studied. The full process of examination of the properties of an object on a model takes place after the model is completely constructed in any form. Everybody knows, for example, that before an airplane is built a model is constructed, either full-scale or scaled down. After the model has been built, one proceeds to study it, such as with wind tunnel testing. It can happen that modeling has occurred with partial examination (an aircraft model has been built), but a full study did not occur -- the aircraft became obsolete.

And now a few words about model examination proper. The authors of the article emphasize that on preparing to fly into the practice area the pilot had studied nothing, but copied a methods elaboration of a flight into the practice area, memorized this copy, and that was the extent of preparing for the mission, that is, no modeling occurred.

But in our daily lives, under actual conditions, things do not happen this way. A methods elaboration is a model of a flight, in this case into the practice area, carried out in the form of a diagram as a model. As a rule such a model indicates the sequence of performance of maneuvers and the principal flight parameters (speed, G-loads, banking, altitude).

And yet every pilot, preparing for a training mission to the practice area, does not simply copy a methods elaboration but prepares his own model, which will be supplemented by considerable information in comparison with the original model. First of all he will consider the weather on the day and even at the hour of the training mission, which cannot be taken into consideration in the original model diagram. Then he will analyze the air situation, which as a rule very strongly influences maintaining altitude and position in the practice area. He will direct attention to the time of day and season, that is, how these elements will affect visibility of ground reference points and orientation as a whole. Many pilots know, for example, that it is considerably easier to fly in the practice area at midday than just before sundown.

Thus the process of supplementing the flight assignment with new elements and analysis of the influence of these elements on its performance constitutes constructing a new flight model and its examination. Having thoroughly analyzed the new model, the pilot concludes on how he can best perform the mission.

There is no doubt that models of different flight assignments require a different volume of investigation. But to one degree or another the element of investigation is characteristic of preparing for any flight.

Further on in the article it is stated that the most graphic example of a symbol model is the scheduled flight operations table. I cannot understand why the authors needed to "make a science" out of an ordinary schedule. Following their logic, everything can be made into a model, and yet the Dictionary of the Russian Language and the Great Soviet Encyclopedia rigorously define what a model is and what modeling is.

It is emphasized at the end of the article that "there exists a certain caution in regard to modeling. The most typical question is the following: can't it be done more simply?" I see nothing reprehensible in this question. Every pilot is a great practical expert. In any theoretical question he perceives first and foremost a practical aspect, that is, how effective the modeling method is in preparing for missions. To demonstrate the effect of modeling and its significance, and in understandable form, is the task of higher educational institutions and scientific research institutes. Pilots should be given methods of studying models which would render substantial assistance in preparing for missions or to a commander in making flight decisions.

Computers and Control

Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 7, Jul 77 signed to press 31 May 77 pp 36-37

[Article by Academician V. Glushkov, Director of the Order of Lenin Ukrainian SSR Academy of Sciences Institute of Cybernetics: "Computer Advances"]

[Text] Computers play an enormous role in a number of branches of science and sectors of the economy. They also occupy a prominent place in the development of aviation and space exploration, particularly in the performance of complex engineering computations in designing modern aircraft, spacecraft, rockets, in automating testing of finished equipment and flight operations control activities.

Today electronic computers serve as a foundation in building air traffic control systems around domestic large airports and even on an international scale. High-intensity traffic and efficient utilization of aircraft becomes practically impossible without computers. Space exploration is inconceivable without computers. With the aid of these machines experts calculate spacecraft trajectories, that is, perform ballistic trajectory computations. Computers help process information received from spacecraft and satellites.

For manned space missions, computers are employed to simulate on the ground both a spacecraft flight and the operation of all its systems. This is essential for swift decision-making in a complex situation, such as when a

system goes beyond the limits of a precisely-specified mission program due to various equipment malfunctions and other unexpected events which can occur as a consequence of any external factors.

In a number of the above-enumerated areas, particularly in the area of automation of complex computations connected with design activities, processing of an enormous mass of information coming in from space, weather forecasting data, for example, computers of ever-increasing capacity are required. It is necessary to expand such computer parameters as speed and increase in the capacity of internal and external memory. The state of and process of development of large computers for these purposes is defined in this country primarily by the uniform series of computers of the nations of the socialist camp (YeS EVM).

This series covers a broad range of computer operating speeds, from tens of thousands to several million arithmetic operations per second. External storage capacity is also rather large. For example, at least 1 million bytes of main memory are offered in the top-of-the-line models of this series, while in principle the figure could be boosted to 16 million bytes (byte -- a symbol which includes two digits or one letter). This is the main memory capacity. External storage volume is also determined chiefly by magnetic disks. Small-capacity (7.25 million bytes) magnetic disks are now being replaced by disks with 29.5, 100, and in the near future 200 million bytes per unit. And quite a few such devices can be connected to a computer.

With the adoption of new systems, the approach to programming is also changing. In the past separate, as a rule not too long programs would be run on the majority of computers, while today there is a capability to run more complex and longer programs. Means of automating programming and program editing are extensively employed for this purpose, making it possible efficiently to run much larger programs. However, in the near future, when incomparably greater speed will be required, such speeds and computation capacities will be inadequate.

Fourth-generation computers will employ large integrated circuits, containing on a single silicon crystal thousands of elementary logic elements with corresponding semiconductor high-speed memory. These computers will come on-line in the current five-year plan, while subsequently they will become the foundation for further growth and development of high-capacity Soviet computer hardware, linking together not one but dozens of such elementary processors. Thanks to this it will be possible to increase summary computer speed from one to three million operations per second (typical of the current period of development of computer hardware), let us say, to 100 million and more, that is, it will be increased by almost 100-fold.

All this is of fundamental significance for increasing accuracy and speeding up calculations and processing of enormous quantities of various data.

It is understandable that weather information utilized for daily forecasts requires very rapid machine processing. An increase in speed of calculation plays an enormous role here. It will become possible to obtain fairly accurate global weather forecasts, initially short-range, and subsequently longer-range. This also applies to the investigation of geologic structure, vegetation cover, as well as many other features of the earth in studying it from aircraft and space vehicles.

The linking together of large computers concentrated at electronic data processing (EDP) centers into large multiple-computer systems is today acquiring great importance. Such systems are being established even with computers which already contain a large number of processors. These complexes in turn are interlinked by means of communications channels and computer systems and are sited at various locations. The result is computer networks which in the final analysis will include all the computer capabilities of a country or group of countries on an international scale. Establishment of such networks is also important for the further development of aviation and space exploration.

During missions in space, for example, information collection points are situated throughout the USSR. If a spacecraft goes out of line-of-sight radio contact with any specific locality, communications with it are not interrupted, and information comes in continuously. Information transmission to a single point for processing is frequently inexpedient. This is why it is essential to have local EDP centers. But then locally processed data will not produce an overall picture of the flight.

In order to obtain a complete picture of a spacecraft mission and on the state of its crew, EDP centers engaged in processing information must constantly exchange data with one another. Consequently an entire network of computers is required.

Similar tasks arise in the case of air traffic control over a large territory. EDP centers concentrated around major airports or at radio navigation beacon sites receive information on air traffic, including monitoring information from air surveillance radars, perform aircraft identification, determine their speed, altitude, etc. When all EDP centers are exchanging information, the entire system as a whole will recreate not simply a mosaic made up of individual little pictures but will present a genuinely objective picture of air traffic within the airspace of a single country or a group of countries. Only with such a system is it possible efficiently to control air traffic and intelligently to utilize alternate airfields. This will increase both the speed and regularity of air traffic, will make flying safer and reduce operating costs.

Such computer systems are also needed for conducting tests, such as for automating wind tunnel tests and experiments involving gas dynamics, scaled-down and full-scale models, and for testing aircraft engines. Computer systems are also essential for total automation of designing complex items, for it is well known that large groups of specialists from different organizations, which are frequently at a considerable distance from one another,

participate in design projects on modern aircraft and spacecraft. Therefore effective work on designing such complex systems is possible only if there is a continuous exchange of information between computers.

And now about the future. It is believed that the fourth-generation computer will be followed by even faster computers designed on the basis of new physical principles. They will extensively employ optoelectronics, holography, and low-temperature technology. They will open up fundamentally new possibilities of increasing the speed of computer elements. There are also ideas on organizing components and separate elements into a system of computers, development of so-called recursive computers. There are also other trends in computer development, making it possible to run computers in parallel, thus obtaining maximum operating speed.

As regards special-application computers, including computers carried on board spacecraft, satellites and aircraft, as well as some auxiliary computers employed for automating testing and simulators, the primary problems (particularly applying to on-board computers) are size, weight and reliability.

With the development of large integrated circuits (LIC), the degree of integration of individual logic elements has reached such a level that a single crystal of silicon measuring a fraction of a square centimeter can in actual fact represent, if not an entire computer, at least individual computer units, accommodation of which in the past required entire equipment cabinets. For example, today a central processor, that is, a computer arithmetic unit and control unit, can be contained on a single chip.

A fairly large volume of high-speed main memory can be provided with two, three, or four LICs. By adding a few more LICs, one can obtain channel equipment which will control communications with input/output devices or with external storage units. As a result of the employment of LICs, the size, weight and power requirements (which is extremely important for on-board equipment) are sharply reduced. In addition, utilization of various devices involving not only simple double and triple equipment redundancy but also the employment of new structural principles increases computer reliability. These include utilization of a special coding system and error-correcting codes within the computer. And not only during transfer of information from one unit to another, as is done today, but directly in the information processing circuits, during performance of arithmetic operations.

Such error-correcting codes make it possible automatically to correct one or even several errors occurring randomly in the process of operation, and thus ensure very high computer reliability, so high that one can replace with a single computer numerous local control systems typical of aircraft of the end of the 1960's and beginning of the 1970's. In the past such systems (autopilots), responsible for an aircraft's movement along specified trajectory, direction and altitude, required special analog equipment, while today these processes can be controlled by an on-board computer.

The role of on-board computers on spacecraft is also becoming greatly enhanced today. They can assume an increasingly large number of diversified functions, with a simultaneous improvement in reliability. Here there arise questions connected with the design of viable systems in which overall output will diminish when certain units fail but the principal task will still be performed. This is extremely important particularly for deep-space exploration. The principle utilized in controlling a lunar rover, where a human operator is on the earth and controls the movement of the vehicle, is inacceptable due to the considerable signal transmission delay. This delay can amount to several hours even within the confines of the solar system.

Therefore it is essential thoroughly to study the possibilities of increasing the capacity of the computers which will be carried on board a spacecraft to Mars, a satellite of Jupiter or other planets in the solar system. Such research is also necessary for building versatile robots which are able to orient themselves independently, to make decisions in unexpected situations and to carry out purposeful behavior. Of course for this it is necessary to solve problems not only involving control of the behavior of the robot proper, but also acquisition of information from the environment for elaboration of purposeful behavior. Thus the robot should have eyes (including a range finder), organs of hearing and touch, and should also be capable of precisely transmitting appropriate information to the central processing unit. Here on the one hand it is necessary to reduce the size and cost of the computer proper, reduce power requirements and weight to a minimum, to increase reliability to a maximum, while on the other hand it is necessary to achieve extremely high operating speed.

The convergence of these two trends in the development of large and small control computers will become possible when large computers will offer even better performance, performing tens and hundreds of billions of operations per second. Then we shall evidently begin developing small control computers as well, which will be equal in computation capacity to today's large computers, or even superior to them. Herein lies the dialectics of development, for in the past we considered minicomputers to mean tens of thousands of operations per second, while today mini- and microcomputers can perform millions of operations per second.

Thus electronic computer hardware comprises one of the most rapidly-developing branches of modern industry. And it is difficult to predict what level of development will be achieved by electronic computers beyond the 20th century, for example. It is obvious that they will be considerably more potent, and it will become much easier for man to work with them.

The line of development of computers connected with an increase in the intellect of computers is important not only for aviation and astronautics but also for the entire national economy as a whole. We are dealing with a transition from simple machine structures to brain-like structures, reminiscent of the structure of the human central nervous system and superior to it in speed of operation and computation capabilities.

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TUTOR SYSTEM AT UKRAINE COMPUTER ENTERPRISES

Kiev EKONOMIKA SOVETSKOY UKRAINY in Russian No 2, 1977 pp 45-49

[Article by N. Taranets, candidate of historical sciences, chairman of the Ukrainian republic committee of the trade union of workers in state institutions: "Tutorship at Computer Enterprises of the Central Statistical Administration of the Ukrainian SSR"]

[Text] The year 1975 and the Ninth Five-Year Plan as a whole were marked by remarkable successes of our people in communist construction, in implementing the Leninist general policy of the Communist Party of the Soviet Union for creation of the material and technical basis of communism.

Just as the whole Soviet nation, workers in state statistics agencies, including in the computer system, numbering 530 computer centers and stations, labored with great enthusiasm and insured early fulfillment of the five-year plan for all production indicators.

The computer system of the Ukrainian SSR Central Statistical Administration fulfilled the Ninth Five-Year Plan by 103 percent with respect to volume of operations in release cost. Over 6,000 people met the five-year plan assignments ahead of schedule, the above-plan volume of operations fulfilled came to 4,966,400 rubles, and in 1975 in particular it came to 1,847,400 rubles. All these results were obtained mainly owing to growth in labor productivity.

Created and incorporated in industrial operation in the Ninth Five-Year Plan was the first phase of an automated system of state statistics, which made it possible to convert more than 40 percent of the statistical reports coming into statistical agencies to system analysis. This has yielded the opportunity to expand considerably the number of indicators processed, to reduce the time for giving out information and, ultimately, to solve more successfully the problems placed before state statistical agencies regarding raising the level of economic analysis and fulfillment of national economic plans and obligations.

For the results of work during the Ninth Five-Year Plan 73 workers in statistical agencies, including 28 tutors in the republic, were given high government awards, over 200 people were given the "Victor in the Ninth Five-Year Plan" badge, and 900 people received the "Victor in the Socialist Competition" badge. Many workers were awarded with honorary certificates, valuable gifts and monetary prizes. The computer center of the L'vovskaya Oblast statistical administration was entered in the Book of Honor for advanced know-how in the national economy of the republic, and the Khustskiy Rayon Computer Center of the Zakarpatskaya Oblast was represented at the All-Union Exhibit of National Economic Achievements of the USSR for introduction of overall mechanization of accounting in all agricultural enterprises of the rayon. The title of shock-worker of communist labor was conferred on 2,400 workers.

The collective of 35,000 people in the computer system of the Ukrainian SSR Central Statistical Administration, inspired by the historical decisions of the 25th CPSU Congress and the 25th Congress of the Communist Party of the Ukraine has actively taken part in the all-union socialist competition. This is shown also by the work during the first half of 1976. The plan for the volume of operations in release cost was fulfilled in six months by 102.6 percent by the computer centers and stations. In the forefront are such organizations as the computer center of the statistical administration of Kiev, the computer centers and stations of the statistical administrations of the Zakarpatskaya, Chernigovskaya, Zaporozhskaya, Chernovitskaya, Khersonskaya, Sumskaya and other oblasts.

The work on the development of the tutor system contributed significantly to fulfillment of production plans, to growth in labor productivity, to increasing the effectiveness of production and to improving the quality of output at computer enterprises. In his speech to the 17th congress of the All-Union Lenin Young Communist League, L.I. Brezhnev noted: "In the working class a new wonderful movement has arisen -- the movement of tutors of young workers. The tutors are experienced workers, possessing a high level of skills, rich life experience and, I would say, the are talented teachers. Voluntarily, with a sense of mission, they are teaching the young people love for work, skills, they are training them in the heroic traditions of our glorious working class. The tutors are as if transferring the baton of labor from the present to the future... It follows to hope that the tutor movement will become a mass one, that it will cover all corners of the country, all the plants, factories, mines, pits, construction sites, kolkhozes and sovkhozes." These words pertain fully also to the workers in state institutions, whose labor plays a significant part in the general cause of the creation of the material and technical basis of communism in our country. Carrying out these instructions, which were developed further in the 24 February 1975 resolution of the Presidium of the All-Union Central Council of Trade Unions and the Bureau of the Central Committee of the All-Union Lenin Young Communist League, "On Further Development of the Mass Movement of Tutors of Young Workers and Kolkhozniks," the economic leaders, the trade unions and

komsomol organizations of the computer system of the Ukrainian SSR Central Statistical Administration under the leadership of party organizations have carried out extensive work for development of the tutor system at computer enterprises of the Ukrainian SSR Central Statistical Administration.

The collegium of the Ukrainian SSR Central Statistical Administration and the presidium of the Ukrainian republic committee of the trade union of workers in state institutions passed a resolution on 18 March 1975, "On Development of the Movement for Tutors of Young People in Statistics Agencies of the Ukrainian SSR," and approved a temporary regulation on tutors in which were set forth the goal and tasks of the tutor system, the duties and rights of the tutor, the forms of incentives for the tutors, a communist friendship agreement between the tutor and the young worker was worked out, the the functions of the council of tutors were determined. The Ukrainian SSR Central Statistical Administration sent a letter to chiefs of oblast statistical administrations "On Organization of Work for Conclusion of Communist Friendship Agreements Between Tutors and Young Workers," and also published and distributed to all computer enterprises of the republic the pamphlet "Broad Scope and Daily Support to the Movement for Tutors of Young People."

The collectives of the oblast statistical administrations and computer enterprises of the republic of the system of the Ukrainian SSR Central Statistical Administration have supported fully the movement for tutors for labor training of the young generation which has unfolded in the country. In the republic computer center and computer centers of statistical administrations of Ivano-Frankovskaya, L'vovskaya, Vinnitskaya, Voroshilovgradskaya and Nikolayevskaya oblasts the discussion of the resolutions mentioned has proceeded in an especially businesslike, thoughtful way.

At expanded joint sessions of local committees, of party and komsomol bureaus and the administration of computer centers, tutors were selected and approved from among the best specialists, who possess high moral qualities and enjoy deserved prestige among the youth. The whole computer system of the Ukrainian SSR Central Statistical Administration at the present time has 2,335 tutors, to whom are assigned 2,745 young workers. Communist friendship agreements have been concluded between the tutors and the young workers.

In order to coordinate the activity of the tutors, to render them practical and methodical assistance, in the labor collectives councils of tutors were set up, approved by a joint decision of the local trade union committees and the committees of the komsomol. These have been made up of veterans of labor, model workers in production, shock workers of the Ninth Five-Year Plan, shock workers of communist labor, and the best workers of the enterprises. The councils of tutors perform their functions in close contact with the administration, they work under the guidance

of trade union and komsomol committees and report to these committees about their activity.

The councils of tutors see to it that young workers needing help are assigned tutors, they control the quality selection of the tutors and make the corresponding reports; they see to improving the ideological-political, vocational, technical and general educational level of the tutors, they render practical assistance and implement control over the work of the tutors regarding the ideological and labor training of the youth, and they generalize the experience of the best tutors.

At the RVTs [rayon computer center] and the Glavmekhchet [main mechanized accounting office] of the Central Statistical Administration of the Ukrainian SSR there are 34 tutors. They are all model workers, shock-workers of communist labor. Four of them have been awarded the "Shock Worker of the Ninth Five-Year Plan" badge, 9 have been given the "Victor in the Socialist Competition of 1974, 1975" badge, and 10 names of the best tutors have been entered on the Board of Honor of the Ukrainian SSR Central Statistical Administration. The work performed by the tutors helps to improve the skills of young specialists. For instance, tutor and head of a group at the RVTs, A.K. Chekerisov, has been working since August 1975 with the young engineer and programmer N.G. Lysenko, who was assigned to him, and has seen to it that at the present time Lysenko has grown into a skilled specialist, a model production worker. Continuing to improve his knowledge, this year already Chekerisov has become the tutor of engineer D.I. Shatrova, who has come to work at the RVTs, and who under Chekerisov's guidance is mastering successfully the specialty of an engineer and programmer.

Deputy chief of the planning division of the Ukrainian main mechanized accounting office P.Ye. Khomenko is the tutor of senior economist V.A. Goyko. In eight months Goyko successfully mastered the specifics of the operation of the planning division, became a model worker in production and accepted a socialist pledge to compete for the award of the title of "Shock Worker of Communist Labor."

A competition among tutors for the title of "Best Tutor of Young People" has developed at computer centers of statistical administrations of L'vovskaya, Ivano-Frankovskaya, Voroshilovgradskaya, Dnepropetrovskaya and other oblasts.

The council of tutors of the L'vov statistical administration and the computer center was set up in June 1975. It was made up of 7 people: the deputy chief of the computer center for statistics Ye.G. Kushnir, who has worked in statistical agencies of L'vovskaya Oblast since August 1944; deputy chief of the division of operation of punch card and keyboard computers R.P. Smurigin; chief of the division of industry statistics R.V. Zebrev; senior economist of the division of capital construction statistics

N.Ye. Bentsionov; senior engineer of the division of technical servicing of punch card and keyboard computers Yu.A. Zubach; chief of the division of algorithmization and programming L.M. Pan'kiv; and chief of the division of electronic computer operation M.D. Petrovich. They are all highly skilled specialists, they have devoted many years of life to improvement of their professional skill and are now actively giving the young people access to it.

All together working in the oblast's statistical agencies are 86 tutors, to whom 158 young workers, who came to work in 1975 and 1976, are assigned. In the computer center and the apparatus of the statistical administration there are 44 tutors. They have concluded agreements with 42 young workers.

The council of tutors under the chairmanship of Ye.G. Kushnir works in contact with party, trade union and komsomol organizations. Concluded between the tutors and the young workers are agreements in which specific obligations are recorded. Much is done here for developing the competition for the title of "Best Tutor of Young People" among the tutors. Organized for the youth are a number of interesting lectures, such as "On the Beauty of Human Relations," "Teaching and Training of Youth," "On Comprehensive Control of Production Quality," "Basic Rules of Labor Legislation," "Basic Directions of Development of the USSR National Economy for 1976-1980," "Youth and the Modern Ideological Struggle," "On the Results of the Work of the 25th CPSU Congress," "Tasks for Workers in State Statistics Ensuing from the Decisions of the 25th CPSU Congress," "The Tutor's Role in the Labor Training of Youth," "The 25th Party Congress about the Party's Economic Strategy," and others.

At the beginning of 1976 the council of tutors prepared and distributed to tutors of statistical agencies in L'vovskaya Oblast the pamphlet "Tutor Prepare a Worthy Replacement for Yourself," in which are disclosed certain methods of working with young people, and there is a discussion of ways to achieve success in this matter.

The council of tutors under the computer center of the statistical administration of Ivano-Frankovskaya Oblast has prepared and issued two symposiums: "An Experienced Tutor for Each Young Worker," and "About the Work of Our Tutors." These, and also the materials on tutorship and the regulations about the tutor system received from the GUVR [expansion unknown] and the Ukrainian SSR Central Statistical Administration have been distributed to all tutors in the oblast.

During 1975-1976 the council of tutors of the computer centers held eight meetings on different problems: study of the regulation on the tutor system, reports of tutors about their work experience, the boundary of the tutor for the young worker, daily attention to tutorship, and so on. The leadership conducted lectures and talks among the computer center tutors about how to shape a Marxist-Leninist world outlook in a young worker,

as well as a communist attitude toward labor and socialist property. There were discussions of materials presented in magazines and newspapers, and talks were held on such topics as "The Path to a Profession" (who should tutor, who should be tutored, how to tutor), the role of tutorship as a school of worker maturity and skill, and so on.

The first oblast convocation of tutors of young people in state statistics agencies was held in September 1975. Taking part in its work were representatives of the oblast committee of the trade union of workers in state institutions, leaders of the statistical administration and computer centers, chiefs, chief engineers of the RIVTs and RIVS [expansions unknown]. All together, 120 people attended.

The chief of the computer center, P.N. Guseva, presented a report about the work of oblast agencies in state statistics for development of the tutor movement. Disclosed in the speeches of tutors and those being tutored was the work experience of the council of tutors, and it was noted that the work of a tutor is work according to the principle "You will work as I do." The methods of this work were disclosed, and there was a discussion about the best tutors.

The participants in the convocation appealed to all young workers in the oblast's agencies of state statistics: always be an example of high consciousness, of discipline and responsibility for what is entrusted to you, love your chosen profession and your own collective.

In February of last year there was an oblast seminar with tutors and members of the council of tutors on the topic "Further Development for the Movement of Tutors." At the seminar there was a discussion of what kind of work the tutors should do in order to help a young worker to master his occupation in condensed periods, how to teach advanced methods of labor and ways to work, how to follow the training of those being tutored, how to help them in everything. Tutors Ya.M. Kaminskaya, Ya.S. Tsyukenda, V.I. Chesnokova and others shared the experience of their work also at trade union meetings.

It is necessary to note that the council of tutors of the computer center of the statistical administration of Ivano-Frankovskaya Oblast works according to a special semi-annual plan. It has drawn up a "tutor corner," a "Best Tutors of the Oblast" stand, and an album "About Our Tutors." A contest for the title "Best Tutor of Young People" has been announced.

Valuable experience has been accumulated also by the council of tutors of the computer center of the Voroshilovgradskaya oblast statistical administration. The best tutors here are: chief of the mechanical analysis division L.K. Kuchay; operator of the tabulation shop of the Krasnodon GIVS [expansion unknown] N.K. Seliverstova and others.

L.K. Kuchay tutors young operator L.V. Poverina, who came to GIVS in September 1975. The young operator mastered the work on punchcard machines for an "excellent," is competing for the title of shock-worker of communist labor and daily fulfills the output norm by 110-115 percent. The apprentice of N.K. Seliverstova is young operator S.I. Kuranova, who in a short period mastered her specialty for a "good" and produces 115-120 percent of the daily output.

In January of last year the computer center of the oblast statistical administration held a meeting with tutors of young people about fulfillment of the communist friendship agreements. A report was presented by G.G. Pereyaslov, veteran of labor and the Great Patriotic War and chief of the personnel sector.

Tutorship at computer enterprises of the system of the Ukrainian SSR Central Statistical Administration has become an important form of instilling a communist attitude to labor in all collectives, it contributes to forming a Marxist-Leninist world outlook in a young person, it develops in him a sense of discipline, of personal responsibility for the matter entrusted, for fulfillment of the plan indicators, the assignments and socialist obligations of the whole collective.

"A personal example -- the best method of work for a tutor" -- this is the slogan under which talks were held for tutors at computer enterprises of Vinnitskaya Oblast. A meeting of tutors -- labor veterans, and young workers was organized at the computer center of the Vinnitskaya Oblast statistical administration for the purpose of exchange of work experience.

One of the best tutors at the computer center, A.V. Kosonogova, has worked as an operator since 1957 and during this time has taught skills to many young women. One of her pupils, L.S. Ostapenko, graduated from the statistics tekhnikum and at present is working as an economist in the labor division, and another pupil, V.K. Mikhaylenko, has been singled out by the entry of her name on the Board of Honor of the oblast statistical administration, where it is next to the name of the tutor, A.V. Kosonogova.

At computer enterprises of Nikolayevskaya Oblast 82 tutors have concluded communist friendship agreements with 94 young workers. Under the guidance of tutor and chief of the division of the computer center V.Ye. Kovalenko, in five years while working full time operator Ye.I. Kravchenko graduated from the statistics tekhnikum, mastered mechanization of accounting fully, was advanced to the post of engineer and at present is herself a tutor. Computer center operator I.P. Maksimenko, a victor in the socialist competition in the system of the USSR Central Statistical Administration, trained operator T.I. Gorbatenko for performance of duties to the full extent.

A tutor at the Volodarsko-Volynskiy RIVTs in Zhitomirskaya Oblast, Z.A. Lavrinchuk, taught young worker I.I. Panchenko the servicing of the PVK M-5000D [expansion unknown] without special courses. The best tutor of the computer center of the statistical administration of Khersonskaya Oblast operator L.Z. Ubiykon' trained 6 card-punching operators in 1976. Tutor S.P. Stepanenko, head of the division of technical servicing of electronic computers of the computer center of the statistical administration of Sumskaya Oblast, taught young worker B.M. Babenko independent servicing of the Minsk-32 electronic computer in a short time. There are many such examples.

At many computer centers of the oblast statistical administration the work of the tutor with young workers is reflected in the red corners, on photo exhibits and stands. For instance a board on "Unity of Experience and Youth" has been organized beautifully at the computer center of the statistical administration of Kiyevskaya Oblast.

Oblast convocations of tutors are held in many statistical administrations of the oblasts jointly with trade union oblast committees in odrder to study, summarize and publicize the work experience of the best tutors. At convocations in Donetskaya, Nikolayevskaya and Khar'kovskaya oblasts an appeal was adopted addressed to all tutors and young workers of the system of the Ukrainian SSR Central Statistical Administration. It is stated in this appeal that the tutors should help a young person who has come to the production facility to master his specialty to perfection, they should teach him the advanced methods of labor, instill in the young worker a sense of pride in belonging to the worker family, inculcate in him the high ideological and moral qualities of builders of communism, help to enlist the young toilers in the social life of the collective, help to disclose and manifest their organizational abilities, and contribute to raising the general educational and cultural level.

Dissemination of the work experience of the best tutors is furthered by the competitions for the title of "Best Tutor of Young People," by special editions of the wall newspapers, meetings and seminars, collective discussion of articles from newspapers and magazines about the work of tutors in other organizations, and the issuing of pamphlets and leaflets.

The collection "Broad Scope and Daily Support to the Movement for Tutors of Young People!" which is issued by the Glavmekhchet of the Ukrainian SSR Central Statistical Administration received approval in the USSR Central Statistical Administration and in the form of exchange of experience it has been sent to all union republics and also to certain statistical administrations of the Russian Federation.

The first steps are being taken regarding organization of the training of tutors. Thus, lessons are conducted according to an approved program once every quarter with the tutors in the statistical agencies of Zakarpatskaya Oblast. In Kiev and Rovno some of the tutors and

representatives of councils from the computer system of statistical agencies attend evening universities of tutors set up under the city and oblast councils of trade unions.

The tutor system has also been widely disseminated in other state institutions of the republic.

The presidium of the republic committee of the trade union jointly with managing agencies of the Ukrainian Ministry of Finance, the republic office of Gosbank, the republic office of Stroybank, and the Main Administration of Gosstrakh [Main Administration of State Insurance] of the rainian SSR adopted joint resolutions and approved Regulations on Tutorship. As of 1 July 1976 in Stroybank institutions in the republic there were 379 tutors, in republic Gosbank institutions there were 794, in Ukrainian SSR Gosstrakh agencies there were 1,718, in Ukrainian SSR State Workers' Savings Banks there were 1,633 and so on.

In April 1976 the republic committee of the trade union jointly with the republic office of Stroybank conducted a republic conference-seminar of tutors with the participation of workers in the oblast committees of the trade union in Kiev.

The tutorship movement contributes to raising the general education level of those being tutored. Thus, just throughout the computer system of the Ukrainian SSR Central Statistical Administration during the 1975-1976 academic year 221 young workers received a higher education and 560 received a secondary specialized education. In the current academic year it is proposed to train up to 260 people in higher educational establishments and up to 600 in secondary specialized educational establishments.

The work experience of the republic committee of the trade union of workers in state institutions and Glavmekhchet of the Ukrainian SSR Central Statistical Administration for development of the tutor system was approved by the collegium of the USSR Central Statistical Administration and the presidium of the central committee of the trade union of workers in state institutions.

Today the movement for tutors in state institutions of the Ukrainian SSR has become still more popular. Also gratifying is that with every day there is an increase in the number of tutors from among the young and highly skilled workers, who even yesterday were tutored by veterans of production and accepted from their hands the baton of tutorship.

However, we understand that all this represents just the first steps in development of the tutor system in state institutions of our republic. Many unsolved problems are ahead. It should be noted that individual local committees of the trade union do not adequately generalize and disseminate the advanced experience in work according to the tutor system; agitation using visual aids and other forms of propaganda of the tutor movement

are not widely used at all institutions and enterprises; still not everywhere have the councils of tutors become the center of practical leadership regarding the teaching and training of young people; certain tutors skillfully impart production skills to the young people, however they do not attract the young people adequately enough to active participation in public life.

The republic, oblast, city, rayon, association and local committees of the trade union jointly with economic agencies are directing their activity to elimination of the noted shortcomings in the development of the tutor system, regarding it as one of the most important forms of improving the quality of work and teaching a communist attitude toward labor.

The committees of the trade union and economic agencies are called upon to manifest more initiative in generalization and introduction of the advanced know-how of tutors for rendering assistance to young production workers in fulfillment of the socialist pledges made by them and in solution of the tasks placed before our nation by the 25th CPSU Congress.

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AUTOMATING THE DESIGNING OF AUTOMATIC, AUTOMATED CONTROL SYSTEMS

Leningrad IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY. PRIBOROSTROYENIYE in Russian No 3, 1977 pp 122-123

[Text] First Scientific-Technical Conference

The First All-Union Scientific-Technical Conference "Automating the Designing of Automatic and Automated Control Systems" was held in Tallin 30 Nov to 3 Dec 76.

The conference was organized by the USSR Ministry of Higher and Specialized Secondary Education, the Estonian SSR Ministry of Higher and Secondary Education, the Committee of the VSNTO [All-Union Council of Scientific and Technical Societies] on Applied Methods in Mathematics and Computers, the Central, Moscow and Estonian republic boards of the Scientific-Technical Society of the Instrument Making Industry imeni Academician S. I. Vavilov, the Moscow Higher Technical College imeni N. E. Bauman and the Tallin Polytechnic Institute.

In accordance with the decisions of the 25th CPSU Congress on accelerating the rates of scientific-technical progress as a decisive condition for the effectiveness of social production and improvement in product quality, the conference set itself the goal of discussing and weighing the overall status and reaching recommendations in the field of developing automatic designing systems (ADS) for automatic and automated control systems. At the conference results of scientific research in this field conducted in the higher educational institutions of the country were discussed; the main prospects and difficulties in building ADS and automatic and automated control systems --whose elimination will mean effective use of available scientific results-- were uncovered; this will help to speed the introduction of automatic and automated control systems in various sectors of the national economy.

A total of 36 papers and 5 reports was given. The conference had 154 participants. Taking part in the conference were representatives of 25 non-higher educational organizations--scientific research institutes, industrial enterprises and so on.

These main questions were taken up:

Principles of constructing automated designing systems for automatic and automated control systems.

Process of automated designing of systems.

Methods of optimization and multicriterial tasks.

Automation of the designing of digital control and information subsystems of automatic control systems and their software.

Standard applied software and reliability criterion for automating the designing of automated control systems and automatic systems for process control.

Languages for automating the designing of control systems.

The conference was begun by the conference chairman, Doctor of Technical Sciences, Professor, honored leader in RSFSR science and technology, State Prize Laureate, V. V. Solodovnikov. B. G. Tamm, academician of the Estonian SSR Academy of Sciences, greeted the conference participants.

Given at this session was a paper by Professor V. V. Solodovnikov, "Problem of Automating the Designing of Automated and Automatic Control Systems and Tasks of the Conference." The paper examined features of automated systems for designing automated and automatic control systems and automatic systems for process control in comparison with automated systems for designing machines, instruments and their components, current directions in the advancement of the theory of automatic designing of automated and automatic control systems; an evaluation was given for the overall status of this theory and requirements imposed on the theory by the practical tasks of designing automated and automatic control systems.

At the session devoted to the subject "Principles of Constructing Automated Systems for Designing Automated and Automatic Control Systems," the following papers, among others, were delivered: (Moscow Higher Technical School), Moscow, V. V. Solodovnikov and S. K. Arutyunov, "Formalization of the Process of Automating the Designing of Control Systems"; (Chelyabinsk Polytechnic Institute), Chelyabinsk, R. T. Chaptsov, "Constructing and Implementing the Inventory System for the Formalized Designing of Automated Control Systems"; (Moscow Pedagogical Institute), Yoshkar-Ola, V. S. Trakhtenberg, and V. Ye. Ivanov, "Developing a System for Automating the Designing of Automated Control Systems" and others.

Of the papers devoted to the subject "Process of Automated Designing of Systems," mention must be made of these: Yu. M. Ageyev and A. N. Barkovskiy (Tomsk Polytechnic Institute, Tomsk), "An Approach to Solving the Problem of Automating the Designing of Automatic Systems for Process Control"; S. K.

Artyunov, Ye. S. Lobusov and A. I. Zhil'tsov (Moscow Higher Technical School, Moscow), "Operational Real-Time Systems in Tasks of Automating Designing"; V. V. Voinov and L. T. Kakichev (branch of the Moscow Higher Technical School, Kaluga), "Problems of Automated Selection of Main Characteristics of Automated Control Systems in the Initial Stage of Designing and Some Methods of Their Solution."

The following papers were read at the session "Methods of Optimization--Multicriterial Tasks": A. I. Petrov and A. A. Shirokov (Moscow Aviation Institute imeni Sergo Ordzhonikidze, Moscow), "Automating Preliminary Designing in the Construction of Automated Control Systems"; V. A. Volkovich, L. F. Dareyko and Ye. P. Lavriyenko (Institute of Crystallography, Ukrainian SSR Academy of Sciences, Kiev), "Aspects of Algorithmization of the Designing of Complex Control Systems"; V. N. Vinokurov, D. P. Vent et al. (branch of the Moscow Chemical Technology Institute imeni D. I. Mendeleyev, Novomoskovsk), "Multicriterial Approach to the Task of Automated Designing of Control Systems Jointly with the KhTS."

At the session "Automating the Designing of Digital Control and Information Subsystems of Automatic Control Systems and Their Software," these papers were heard: O. P. Sitnikov (Ural Polytechnic Institute imeni S. M. Kirov, Sverdlovsk), "Automating the Designing of Structures and Software of Multiprocessor Computer Systems (Automatic Systems for Process Control)"; V. I. Vezenov and V. P. Koryachko (Ryazan' Radiotechnical Institute, Ryazan'), "Methods of Automatic Designing of Multiproeessor Information Processing Systems"; V. V. Solodvnikov and V. F. Biryukov (Moscow Higher Technical School, Moscow), "Solving Certain Problems in Automating the Designing of Control Systems on the Basis of the Complexity Principle."

The program of the session "Standard Applied Software for Automating the Designing of Automated Control Systems and Automatic Systems for Process Control and the Automating of Designing in Terms of the Reliability Criterion" included these papers: V. Ye. Semenov, N. P. Demenkov et al. (Moscow Higher Technical School, Moscow), "Principle of Organizating Applied Algorithmic and Mathematical Software for (Systems for Automating the Designing of) Automated and Automatic Control Systems"; and V. G. Terent'yev and A. A. Zhuchkov (Moscow Engineering Physics Institute, Moscow), "Automating the Reliability Designing of Subsystems of Automatic Systems for Process Control," and so on.

At the session "Languages for Automated Designing of Control Systems," a paper by G. S. Chkhartishvili, L. P. Chkhartishvili and N. G. Lyukin (Moscow Power Institute, Moscow), "Dialog System for the Analysis and Synthesis of Automated Control Systems," and so on

Expanded abstracts of papers included in the work of the conference were published in two editions of abstracts of the papers, published by the Moscow Higher Technical School imeni N. E. Bauman and Tallin Polytechnic Institute (Tallin).

At the concluding session, a decision was passed to hold the Second All-Union Scientific-Technical Conference "Automating the Designing of Automatic and Automated Control Systems" in 1979.

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AIMS, METHODS, FEATS OF METEOR RESEARCH EXPLAINED

Moscow NAUKA I ZHIZN' in Russian No 8, 1977 pp 54-62

[Article by P. Babadzhanov, Academician of the Tadzhik SSR Academy of Sciences: "Space Wanderers"]

[Text] On a clear dark night, especially in the middle of August, November and December, one can see "falling stars" drawing lines in the sky. These are meteors, an interesting natural phenomenon known to man since time immemorial. Meteors, especially in recent years, have been attracting the tireless attention of astronomical science. They have already told us much about our solar system and about the Earth itself, particularly about the earth's atmosphere. Moreover, meteors have, figuratively speaking, paid back the debt, reimbursing the funds spent on studying them by contributing to the solution of certain practical problems of science and technology. Meteor research is being actively developed in a number of countries, and our brief account is dedicated to some of this research. We shall start it with a more exact definition of terms.

An object which is moving in interplanetary space and has dimensions, as they say, "greater than molecular but less than asteroidal," is called a meteoroid, or a meteor body. On invading the earth's atmosphere, a meteoroid (or meteor body) is heated to incandescence, lights up brightly and then ceases to exist, having been transformed into dust and steam.

The luminous phenomenon caused by the burning of the meteor body is called a meteor. If the meteoroid has a comparatively large weight and if its speed is not relatively great, a part of the meteor body, not having been completely consumed in the atmosphere, sometimes falls to the earth's surface. This fallen part is called a meteorite. Extraordinarily bright meteors which have the form of a fireball with a tail or a burning firebrand are called bolides. Bright bolides can sometimes be seen even in the daytime.

Why Meteors Are Studied

Meteors have been observed and studied for centuries, but only in the last three or four decades have their nature, physical properties and orbital

characteristics been revealed. Researchers' interest in meteoric phenomena is associated with certain groups of scientific problems.

First of all, a study of meteor trajectories and the processes of luminescence and ionization of meteoroid matter is important for an explanation of physical nature, for they, meteor bodies, are, after all, visitors to the earth, "samples" of the substance of distant regions of the solar system. Moreover, a study of some of the physical phenomena which accompany the flight of a meteor body yields rich data for study of the physical and dynamic processes which are occurring in the so-called meteoric zone of our atmosphere, that is, at altitudes of 60-120 kilometers. It is here mainly that meteors are observed, meteors remaining the most effective "research tool" for the study of these atmospheric layers, even against the background of the current scope of research with spacecraft. Direct methods of studying the upper layers of the earth's atmosphere by means of artificial earth satellites and high-altitude rockets began to be widely used 20 years ago, during the International Geophysical Year. Artificial satellites yield information about the atmosphere at altitudes of more than 130 kilometers, but at the lower altitudes they simply burn up in the dense layers of the atmosphere. As for rocket measurements, these are conducted only above fixed points of the earth and are short term in nature.

Meteor bodies are full-fledged inhabitants of the solar system, revolving in heliocentric orbits which ordinarily have the form of an ellipse. By evaluating how the total number of meteoroids is distributed by groups with various weights, speeds and directions, it is possible not only to study the whole complex of small bodies of the solar system, but also to create a basis for constructing a theory of the origin and evolution of meteoric matter. Interest in meteors has grown recently also in connection with intensive study of near-earth space. An appraisal of the so-called meteor hazard on various space paths has become an important practical problem. This, of course, is only a particular question. Space and meteor studies have very many points of contact, and the study of meteoric particles has become a firm part of the space program. Thus, for example, valuable information has been obtained from satellites, space sounders and geophysical rockets about the smallest meteoroids which are moving in interplanetary space. Here is just one figure: sensors installed on spacecraft enable the recording of impacts of meteoroids which are measured in thousandths of a millimeter (!).

How Meteors Are Observed

On a clear, moonless night meteors can be observed down to the 5th and even 6th stellar magnitudes—they have the same brightness as the faintest stars discernible to the naked eye. But mainly it is the somewhat brighter meteors, those brighter than the 4th stellar magnitude, which are visible to the naked eye; in an hour an average of about 10 such meteors can be seen. All told, 90 million meteors per day which could be seen at night enter the earth's atmosphere. The total number of meteoroids of

various sizes which arrive in the earth's atmosphere in a day is in the hundreds of billions.

In meteor astronomy it has become customary to divide meteors into two classes. The meteors which are observed every night and move in the most varied directions are called random or sporadic meteors. The other type is the periodic or nonsporadic meteor. These are observed at the same time of the year and from a definite small portion of the terrestrial sky—a radiant. This word—radiant—means in this case a "radiative sector."

Meteor bodies which give birth to sporadic meteors move independently of each other in space in the most diverse orbits, but the periodic ones move in almost parallel paths, which originate from exactly the same radiant.

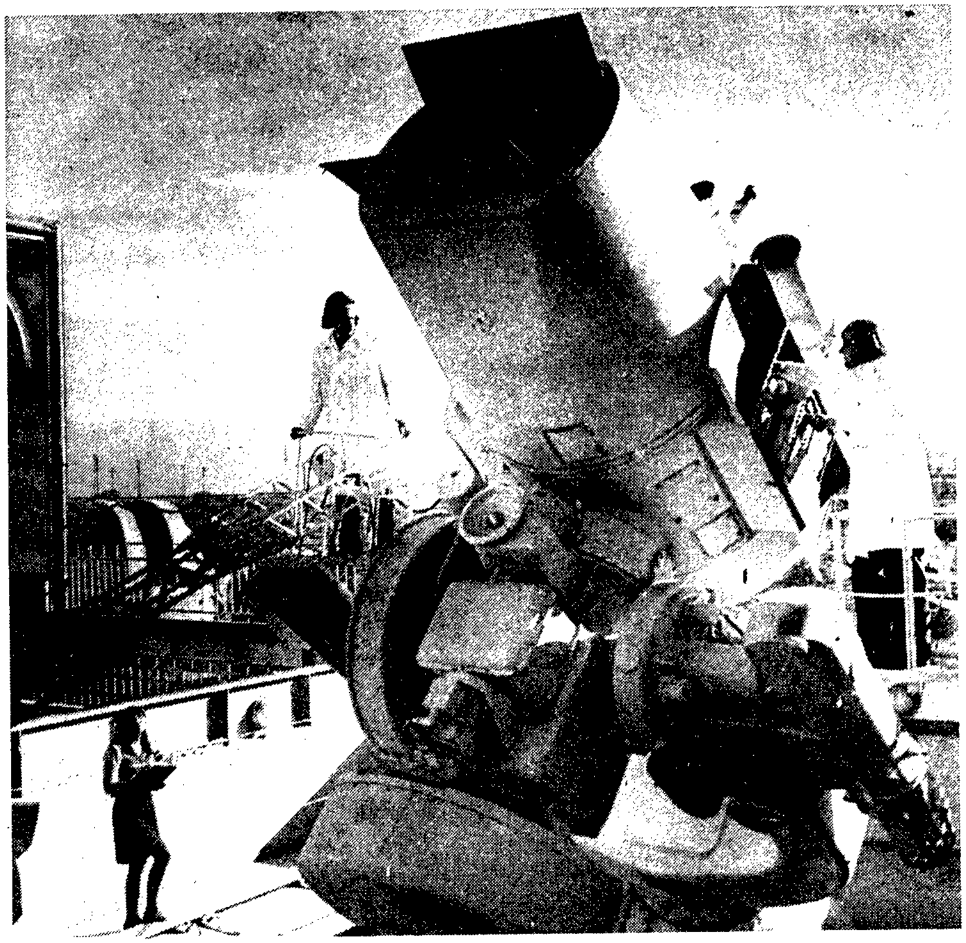
Meteor streams are named from the constellations in which their radiants are located. For example, the Leonids are the meteor stream with the radiant in the constellation Leo, the Persids in the constellation Persius, the Orionids in the constellation Orion, and so on. Knowing the precise position of the radiant and the time and speed of the meteor's flight, it is possible to computed the meteoroid's orbital elements, that is, to disclose the nature of its movement in interplanetary space.

Visual observations have permitted important information to be obtained about daily and seasonal changes in the total number of meteors and about the distribution of radiants throughout the celestial sphere. But mainly photographic, radar and, in recent years, electronic-optics and television methods of observation, have been used for research.

Systematic photorecording of meteors began about 40 years ago, and the so-called meteor patrols use it for this purpose. A meteor patrol is a system made up of several photographic units, each consisting usually of 4-6 wide-angle photographic cameras which are installed in such a way that they cover as large an area of the sky as possible.

By observing a meteor from two points 30-50 km apart, it is easy to define its altitude, trajectory in the atmosphere, and radiant from photographs. If a shutter is placed in front of the cameras of one of the patrol units, that is, a rotating shutter, then the meteoroid's speed can also be determined, for instead of a continuous track on the film, a hatched line is obtained, the length of the lines being exactly proportional to the meteor body's speed. If prisms or diffraction gratings are placed in front of the lenses of the cameras of another unit, then the meteor's spectrum will appear on the plate, similar to the spectrum of a solar light spot which passes through a prism and onto a white wall, and the meteoroid's chemical composition can be determined from the meteor's spectrum.

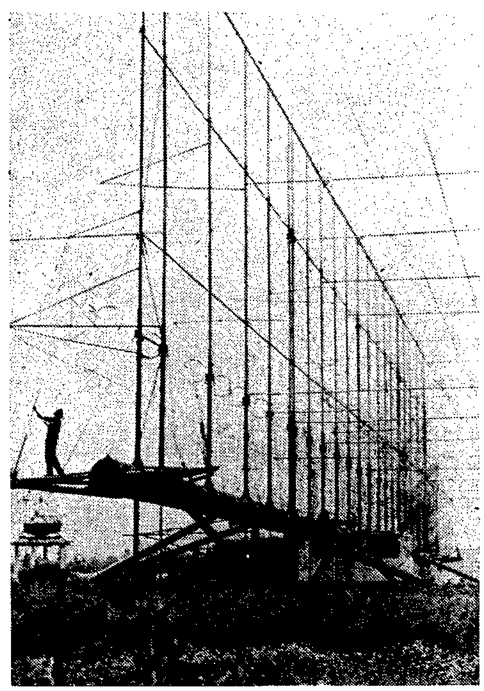
One of the most important virtues of radar methods is the possibility of observing meteors in any weather and around the clock. Moreover, radar permits the recording of very faint meteors, down to the 12th-15th stellar magnitudes, which are produced by meteoroids weighing millionths of a gram, and even less.



Institute of Astrophysics of the Tadzhik Academy of Sciences.
A reflecting telescope used for photographic meteors.

Unit with Rotating Shutter, of the Meteor Patrol of the Gissar Observatory of the Institute of Astrophysics of the Tadzhik SSR Academy of Sciences.

The radar locates not the meteor body itself but its trail: the meteor's atoms which are vaporized in moving through the atmosphere collide with air molecules, which become excited and turn into ions, that is, free charged particles. Ionized meteor trails are formed which are several tens of kilometers long and have initial radii on the order of a meter; these are by nature suspended (not for long, of course!) atmospheric conductors or, more precisely, semiconductors—made up of 10^6 to 10^{16} free electrons or ions per centimeter of trail length. Such a concentration of free charges is completely adequate for meter-band radiowaves to be reflected from them, as from a conducting body. As a consequence of diffusion and other phenomena, the ionized trail quickly expands, its electron concentration drops, and it is dissipated by upper atmosphere winds. This enables radar to be used to study the speed and direction of air currents, for example, for study of the global circulation of the upper atmosphere. Joint forces of scientific workers of the Institute of Astrophysics of the Tadzhik SSR Academy of Sciences and of the Khar'kov Institute of Radio-Electronics organized in due course a special equatorial expedition, and for 2 years conducted synchronized observations of the drifting of meteor trails and of ionospheric inhomogeneities in the regions of Mogadiscio (Republic of Somalia), Khar'kov and Dushanbe.

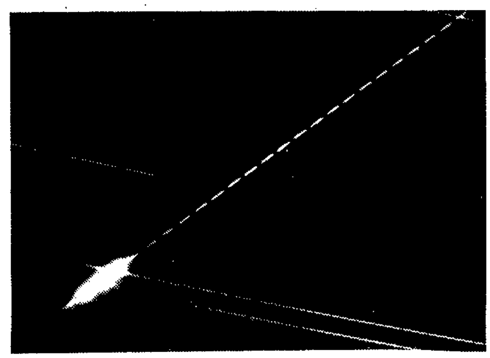


Radio-Engineering Complex of the Institute of Astrophysics of the Tadzhik SSR Academy of Sciences for Observing Meteors and Ionospheric Inhomogeneities.

In recent years observations of very bright bolides, which sometimes accompany meteor falls, are being conducted increasingly actively. Bolide observation networks with "whole sky" cameras have been organized in several countries. They actually monitor the whole sky but record only very bright meteors. Such networks are made up of 15–20 posts which are located at distances of 150–200 kilometers, and they cover large territories, since the intrusion of a large meteoroid into the earth's atmosphere is a comparatively rate phenomenon. And here is what is interesting: of the several hundred bright bolides which have been photographed, only three have accompanied meteor falls, albeit the speeds of the large meteoroids were not very great. This means that the surface explosion of the Tunguska meteorite of 1908 was a characteristic phenomenon.

The Structure and Chemical Composition of Meteor Bodies

The intrusion of meteor bodies into the earth's atmosphere is combined with the complex processes of its destruction—melting, vaporization, dispersion and fragmentation. Atoms of meteor matter, when colliding with air molecules, are ionized and excited: the luminosity of meteors is caused basically by the radiation of the excited atoms and ions, which move with the speed of the meteor body itself and have kinetic energies of from several tens to hundreds of electron-volts.



Photographs of a meteor made without a rotating shutter (above) and with a rotating shutter (below).

Photographic observations of meteors by instantaneous exposures (on the order of 0.0005 second) were developed and realized for the first time in the world in Dushanbe and Odessa, and they demonstrated graphically the diverse types of fragmentation of meteor bodies in the earth's atmosphere. Such fragmentation can be explained both by the complicated nature of the processes themselves of meteor-body destruction in the atmosphere, and by the loose structure of the meteoroids and their low density. Of especially low density are the meteor bodies of cometary origin.

Bright emission lines mainly are visible in the meteor spectra. Among them are observed the lines of neutral atoms of iron, sodium, manganese, calcium, chromium, nitrogen, oxygen, aluminum and silicon, as well as the lines of ionized atoms of magnesium, silicon, calcium and iron. Much like meteorites, meteor bodies can be divided into two major groups: iron and silicon groups, the silicon meteoroids being much more common than the iron ones.

Meteoric Matter in Interplanetary Space

Analysis of the orbits of sporadic meteorites indicates that meteor substance is concentrated mainly in the plane of the ecliptic (the plane in which the planets' orbits lie) and move around the sun in the same direction that the planets themselves move. This is an important conclusion, for it proves the commonality of the origin of all bodies of the solar system, including even such small ones as meteoroids.

The observed speeds of meteoroids relative to the earth are in the 11-72 km/-sec range. But the speed of the earth's motion about its orbit is equal to 30 km/sec, and that means that the speeds of the meteoroids relative to the sun do not exceed 42 km/sec. That is, it is less than the parabolic speed which is required for escape from the solar system. From this comes the conclusion that the meteoroids do not come to us from interstellar space but belong to the solar system and move around the sun in closed elliptical orbits. Based upon photographic and radar observation, the orbits of several tens of thousands of meteoroids have been determined.

In addition to the gravitational attraction of the sun and the planets, the forces caused by the interaction of the sun's electromagnetic and corpuscular radiation exert a considerable influence on the motion of meteoroids, especially the small ones. Thus, in particular, under the influence of the pressure of light, the smallest meteoric particles, of sizes less than 0.001 mm, are ejected from the bounds of the solar system.

Moreover, the braking effect of radiation pressure (the Poynting-Robertson effect) also exerts a substantial effect on the motion of the small particles, and because of this the orbits of the particles are gradually "contracted," and they increasingly approach the sun. The lifetimes of meteoroids within the inner regions of the solar system are not great, and so the reserves of meteoric matter must gradually be replenished.

Three main sources of such replenishment can be pointed out: 1) the breakup of the nuclei of comets, 2) the fragmentation of asteroids (let us recall—these are small planets which move mainly between the orbits of Mars and Jupiter) as a result of mutual collisions, and 3) the stream of very small meteoroids from distant neighborhoods of the solar system where, probably, the remains of matter from which the solar system was formed is found.

Meteor Collectives and Solitary Meteors

The average number of meteors which are observable by the naked eye within an hour usually lies within the 6-16 range, but it can sometimes reach 50-100. This occurs when the earth encounters a swarm of meteoroids—such a swarm occurring as a result of the discharge of meteor bodies from the nucleus of a comet, which, as is known, is a conglomerate of frozen gases and solid particles. Such a breakup occurs comparatively close to the Sun, at a distance of less than half the Sun-Earth interval; after being accelerated a certain amount, having received some acceleration during the breakup process, the meteoroids transfer to orbits which are easily distinguished from the orbit of the comet itself.

A certain scattering of the swarm also occurs along its average orbit, and as a result, after several tens of revolutions, a closed elliptical ring is formed in which meteoroids are distributed approximately evenly. Once per year this ring crosses the earth and, therefore, at a definite time, intense meteor streams are observed each year.

If a swarm is relatively young, then the main weight of the meteor matter still has not managed to become evenly distributed throughout the orbit but is concentrated in a small part of it. The earth thus encounters this section, not annually of course, but then each encounter is accompanied by an extraordinarily intense meteor stream—1,000 or more meteors per minute. These were the so-called meteor showers, which include the Andromedoids (meteor showers in 1872 and 1885), the Draconoids (in 1933 and 1946) and the Leonids (1789, 1833, 1866 and 1966).

Photographic and radar observations of meteors have enabled the orbits of several hundred meteor swarms to be determined. An indisputable connection of certain swarms with known or "currently healthy" comets has been established, but for others the comet of origin either has already broken up (for example, the comet Biely, the progenitor of the Andromeda meteor swarm), or, under the influence of the large planets, has sharply changed its orbit. Even in such large swarms as the Perseids and the Geminids, meteoroids are not distributed as densely as would seem: a meteor body which gives birth to a meteor which is visible to the naked eye is separated from another such body by hundreds of kilometers. And this fact, which is observed for many meteors when the earth encounters a meteor swarm, is explained by the enormous speeds of all participants of the cosmic "road traffic"—of the earth itself and of meteor bodies. At the same time, for the compact meteor swarms, which give birth to meteor showers (the Leonids of 1966—15,000 meteors per hour!), the distance between meteoroids is 20-30 km.

During the last 30 years a number of new meteor streams—meteor associations—have been discovered, based on photographic as well as on radar observations. They do not have a precisely expressed maximum of activity: speeds and orbital elements of meteoroids within the association differ much more than in a meteor stream.

Any "organized assembly" of meteor particles with common kinematic properties is being continuously destroyed. Examples are known of a meteor swarm splitting when two of its parts found themselves on opposite sides of the ecliptic.

On the other hand, the gravity of the large planets, especially Jupiter and Saturn, can change the orbits of meteor swarms in such a way that they approach the earth's orbit. Questions of the evolution of small bodies of the solar system are in an intensive stage of study, but it is already clear that sporadic meteoroids are being formed as a result of the breakup of meteor swarms, and meteor associations are, apparently, an intermediate stage between an ordered stream and the sporadic background, and these associations, just like swarms, were produced by comets.

A portion of the sporadic meteors belong to fairly diffused meteor streams or associations and, consequently, are also connected with comets in other than their kinematic characteristics (dimensions, shape and position of the orbit in space) while others are close to the asteroids and were formed as a result of collisions thereof.

The spatial structure of meteor swarms is of great interest. Their lateral cross-section can be judged by the duration of the meteor stream itself; for some swarms it lasts a fairly long time, but for others, those which have a compact central part, it occurs comparatively quickly. Thus, for example, a month is required for the Perseid swarm to pass, and this means that the stream's girth is about 80 million km. But the Quadrantids pass in about 10 hours, and its "thickness" is about 1 million km.

Naturally, meteor bodies encounter not only the earth but other planets of the solar system also. For planets and their satellites which are not protected or are weakly protected by an atmosphere, encounters with meteor bodies lead to destructive consequences, in particular to the formation of numerous craters and holes. Photographs of the surfaces of the Moon, Mars and Mercury which were obtained at close distances by Soviet and American automatic interplanetary spacecraft confirm this.

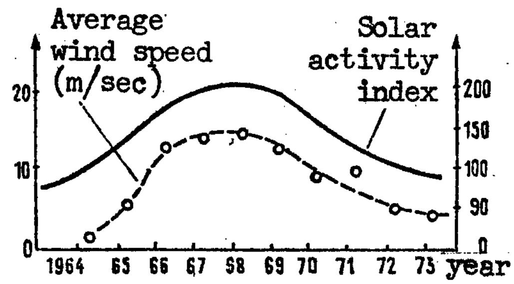
The Meteor Geophysical Service

A comparatively short time ago information about the atmosphere's meteor zone was based mainly on data obtained from observations of meteors. Now results have been obtained from theoretical computations and numerous experimental data which fairly satisfactorily characterize the density and other of the most important parameters of the atmosphere at all altitudes. And this will enable the solution of reciprocal problems of meteor physics—to make more precise the physical theory of meteors and the structure of meteor bodies themselves. Moreover, based on systematic observations of meteors, it is already possible to define seasonal and diurnal changes in physical parameters of the atmosphere in the shifting meteor zone and to determine the dependence of these changes on the place of observation. This is one of the important practical contributions of meteor astronomy in solving important applied problems, in this case in the study of climate and weather forecasting.

Meteor observation radar stations in Dushanbe, Kazan', Moscow, Frunze, Khar'kov and other cities of the country regularly keep track of the drift of meteor trails and collect important information about the properties of the circulation of the earth's atmosphere. These indicate that in the middle latitudes, at altitudes of 70–130 km, the regular wind is practically horizontal, although there also exist vertical atmospheric movements which are localized in time and space. The regular nature of diurnal and seasonal changes in wind speeds has been confirmed, these changes having a great similarity at various altitudes and the predominant direction of the air mass being from West to East. Wind speeds increase with height—in the 90–120 km interval the speed increases an average of 2 m/sec per km rise in elevation.

Many years of radar observations of meteor trace drift above Dushanbe confirm graphically the theoretical hypotheses that, along the local vertical wind speed is proportional to the square of the atmosphere's temperature. Such a simple dependency of wind speed on temperature is correct

for altitudes of 20–140 km. Below 20 km the picture is complicated by the influence of the subjacent surface, cloud masses and vertical air streams, and above 140 km the earth's magnetic field, solar corpuscular radiation streams and other factors must be considered.



Solar Activity as a Function of Wind Speeds at High Altitudes.

Lengthy observations of meteors have enabled the precise dependence of wind motion on the energy of solar activity to be observed. During years of maximum activity the average wind speed is maximal, while in years of minimum activity it is minimal. During the 11-year cycle 1964–1974 the average wind speed changed by a factor of 2. This can be explained by an increase in the flow of short-wave solar radiation during the years of maximum activity, which led to an increase in the temperature of those layers of the upper atmosphere where this radiation is absorbed.

The circulation of the earth's atmosphere at great altitudes is a powerful process of a complicated nature. It has an indisputable effect on upper atmosphere processes.

The Flow of Meteoric Substance onto the Earth

The greater the mass of a meteoroid which invades the earth's atmosphere, the brighter the meteor (where other conditions are equal) to which it gives birth. Based on an estimate of all the meteors which are observed in the earth's atmosphere in a day, it is possible to assess the total mass of the meteoroids of various brightnesses. In making these computations it was found that with a decrease in the brightness of meteors by one stellar magnitude, the number proves to be almost 150 percent greater.

In the near-earth region the density of meteor matter is about $0.5 \cdot 10^{-22}$ g/cm^3, but from tens to hundreds of tons of meteor substance fall on the earth per day, mainly in the form of dust. At first glance this is a lot, but such a weight could not change our earth's face essentially even during the billions of years of its existence. At the same time, the stream of meteor substance exerts a substantial influence on the gaseous, ionic and aerosol composition of the earth's upper layers, which help to form the so-called noctilucent clouds, and certain layers of the ionosphere, and it also participates in other processes in the upper atmosphere.

Meteor Radio Communications

The reflection of meter-band radiowaves by meteor trails has enabled the creation of a system of long-range radio communications on ultrashort waves which, as is known, are among the radiowaves of short-range effect.

On the earth's surface, UKV's [ultrashort waves] are propagated only at line-of-sight distances and they simply "puncture" the ionosphere, unlike short waves, which are reflected from it, as from a mirror, and this is why they travel thousands of kilometers. Meteor trails can play the role of this mirror for UKV's.

In two-way meteor radio communications, the transmitters of both parties irradiate a certain zone at the height at which meteors appear—usually this is 100 km above the earth's surface. The receiving antennas are also aimed toward this same zone. At the moment of the appearance of a "mirror," that is, the appearance of a definite ionized meteor trail, the radio signal travels from the transmitters to the receivers, and the automatic electronic equipment includes apparatus for the transmission and reception of the information. During a pause, when the needed meteors are lacking, information does not pass in the communications channel. It is accumulated in special electronic units, to await the moment when a meteor will appear and the unit will be able to deliver the next "burst." The necessity to watch for the appearance of meteors and to make the transmissions in short "bursts" is, of course, inadequate. But it is compensated for by many virtues of meteor communications, for example by these: it is affected comparatively little by interference and ionospheric disturbances, and it requires only transmitters of small power, usually 0.5-2 kw. Even where there is strong competition with other forms of radio communication, particularly satellite, meteor communication continues to progress.

The Meteor Hazard

Data about the spatial density of meteoric material and also about the percent content of meteoroids of various weights in interplanetary space enables the so-called meteor hazard for spacecraft to be assessed.

Let us note at once that the probability of an encounter of a spacecraft with a random meteoroid is greater the smaller the size of the meteoroid, since the number of the smallest meteoric particles greatly exceeds by many times the number of larger particles. Appropriate computations have been obtained from data about the flow of meteoric substance, and special experiments indicate that in space a collision of a 1 m^2 surface with a particle larger than 1 mm can average once in several decades. Collisions with the smallest particles, of micron size, occur millions and tens of millions of times oftener, and it can be realistically expected that a spacecraft will receive about one impact per second from such particles. There will not be serious wear of the spacecraft's metal covering from this bombardment, but unprotected optical surfaces, let us say, and telescope lenses and other instruments, which are affected by the "sandblast effect," under the action of meteor erosion, can prove to be substantially worn down after several years.

Large meteor streams can increase the meteor danger in a very small degree: the appearance of meteor streams affects the small meteor-body

count much less than it does the large-body count, but the share of large meteor bodies in a stream is comparatively small.

All these factors, which are, in general, reassuring, do not in the least mean that the meteor danger can be immediately and forever disregarded, that one can forget about it. Entirely to the contrary, as space flights cover longer routes and last longer times, increasingly deeper research of meteor phenomena will undoubtedly be necessary in order to find a guarantee for full meteor safety.

What has been said here is, of course, actually fragmentary, only about certain aspects of "falling star" (or meteoroid) research, and about the practical use of these operations. Many consistencies of the motion and physical characteristics of meteor bodies have been adequately clarified, and the knowledge gained here is of practical application. But, of course, much remains to be done to explain precisely the role of meteor matter in the origin and evolution of the solar system, to accumulate new information about meteors and meteoroids and to use this information in solving applied problems of geophysics, astronomy, meteorology, radio engineering, astronautics and other areas.

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TELEVISION A VALUABLE TOOL FOR METEOR RESEARCH

Moscow NAUKA I ZHIZN' in Russian No 8, 1977 pp 58-62

[Article by S. Mukhamednazarov, scientific worker of the Engineering-Physics Institute of the Turkmen SSR Academy of Sciences: "Meteors on the Television Screen"]

[Text] A meteor is usually observed only for a fraction of a second, but much information about it can be collected during this period. Using special methods of photography, particularly exposure through a rotating shutter and spectrography, astronomers can determine the initial mass of a particle and the course of its vaporization, the speed and braking of the meteor in the atmosphere, the chemical composition of the particle, and the physical conditions in the gas blanket and in the thickened air on the meteor's path.

Until recently astronomers could record only comparatively bright meteors. Even with large wide-aperture lenses, they managed to photograph meteors only to the 4th stellar magnitude—similar to the light from stars of average brightness visible to the naked eye. As for spectra, these could be obtained only from the very brightest meteors.

It would seem that there would be a simple path for observing fainter meteors—for which the use of lenses of still wider aperture would be necessary. However, the astronomers could not take this route: the lens aperture ratio is increased at the expense of the field of view, and in so doing the probability of "catching" a meteor is sharply reduced, because we do not know ahead of time where and when it will fly, so it is desirable to observe a fairly large section of the sky. And such an effective method as "fishing out" weak targets by increasing exposure time during photography is entirely unacceptable. The fact is that the meteor is a moving object, you cannot tell it, "Be still! I'm taking your picture," and the meteor itself allots the maximum possible exposure time—the time of its motion in the field of view of the lens is usually tenths of a second. All of this taken together led right to the fact that small meteors remained inaccessible to precise measurements for a long time. It is true that for 30 years now radar has helped astronomers who observe meteors.

Radar installations record very weak meteors, even those invisible to the eye, but the equipment can by no means tell about the composition of the meteor or the nature of the luminosity.

A qualitative advance occurred with mastery of the television method of astronomical observations. Television has been used in astronomy since 1952, and this union has enabled the real sensitivity of astronomical instruments to be increased by many times. The rise in sensitivity is caused by the fact that the television tubes which absorb the light themselves possess very high sensitivity; moreover, television transforms the light into electronic signals and these can easily be intensified by tube or transistor amplifiers, raising the system's sensitivity still more.

The first tests indicated that television equipment can raise the real sensitivity of telescopes by tens of times. Usually, in an astronomical television system, aside from the traditional image channel (the television camera which receives the picture, the time-base generators, the amplifiers, the imaging device with ordinary kinescope), the EOP (electronic-optical converter) also joins in, as a rule, and it can raise image brightness at least 20-50 times. The "picture" is projected onto a photocathode EOP, and electrons are knocked out of it which, after being accelerated by an electrical field, fall on a luminescent screen and brighten the image on it. This is a copy of what the photocathode "saw," but the copy is much brighter than the original. The television system for observing meteors with an EOP has been simplified in the drawing. For the first time, the observation of meteors by means of the television system has enabled pictures to be obtained of meteors of the 8th-9th stellar magnitudes, which generally are not visible to the naked eye, and then it became possible to obtain spectra of meteors with a brightness of the 3d stellar magnitude.

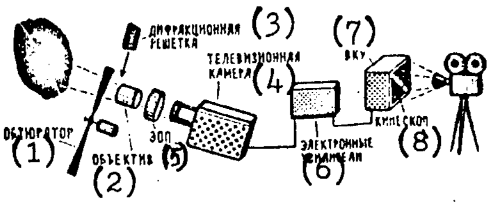
In our country the use of the astronomical television system for studying meteors was started in 1970 in the Astrophysical Laboratory of the Engineering-Physics Institute of the Turkmen SSR Academy of Sciences. An installation was developed and created: a Yupiter-6 input lens projects a sector of 10x10 degrees of the starry sky onto the photocathode of a three-chamber electronic-optical converter (actually three EOP's which follow one another), which intensifies the image's brightness by several thousand times. The intensified image is converted into a video signal by an LI-214 superopticon pick-up tube; after the video signal is intensified it creates an image on the kinescope of the video display monitor—the VKU. Well, and finally the image is photographed on film.

Such a system enables meteors of the 8th-10th stellar magnitudes to be photographed and diverse, previously unknown characteristics of very faint meteors to be obtained.

But perhaps the most interesting results have been obtained by means of television photography of the spectra of meteors. This work has been going on in the Astrophysical Laboratory of the Engineering Physics Institute of the Tadzhik SSR Academy of Sciences since 1972. And here the

television system enabled extremely high sensitivity to be obtained—without difficulty we photograph the spectra of meteors with brightness of the 4th stellar magnitude, which previously were completely inaccessible to spectral research. But especially important is the fact that the possibility appeared of obtaining spectrograms of meteors on several consecutive film frames, which is very important for study of the dynamics of individual spectral lines at various moments of the meteor's flight. Moreover, the ionic trail of faint meteors has become accessible to researchers—the atmosphere at "meteoric" altitudes is very rarefied, and the processes of the ionization and excitation of atoms of such a rarefied gas are of no small interest to physicists.

The results of application of the television method to meteor observation have exceeded all expectations. It has been possible not only to obtain the spectra of faint meteors and their trails but also to discover a number of peculiarities not previously noticed. Thus, for example, the radiation of the molecular ion of nitrogen was reliably established. It never was observed in the spectra of bright meteors, but we have observed it in six spectra of faint meteors. What happened here? Obviously, there are different conditions of nitrogen luminosity for a large and a small meteor body. Astronomers of Moscow, Odessa and Dushanbe have engaged in explaining this phenomenon, and even physicists have been involved.



Basic Components of a Television System for Observing Meteors.

Key:

1. Rotating shutter.
2. Lens.
3. Diffraction grating.
4. Television camera.
5. EOP [electronic-optical converter].
6. Electronic amplifiers.
7. VKU [video monitor unit].
8. Kinescope.

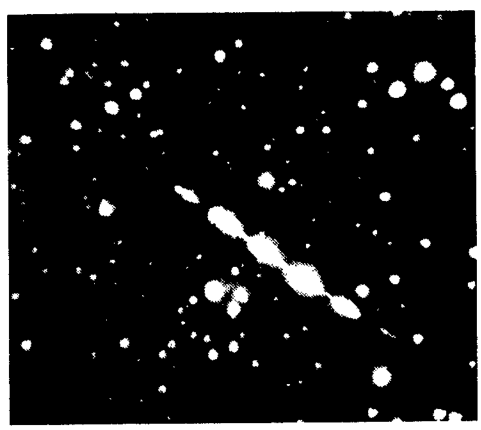
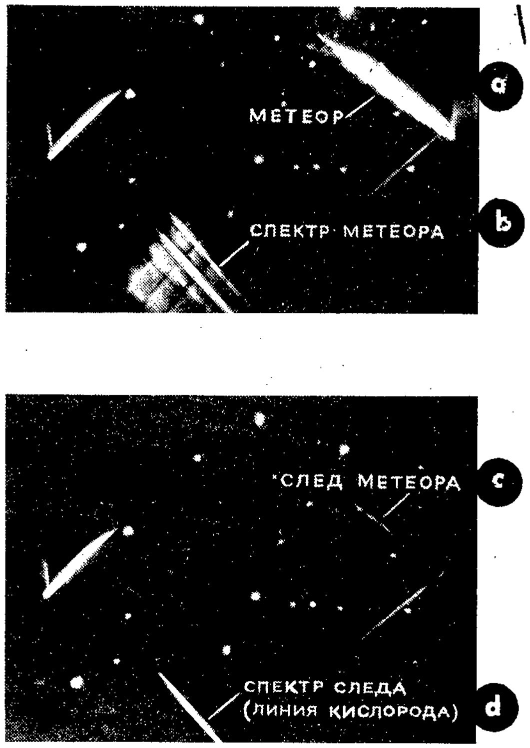


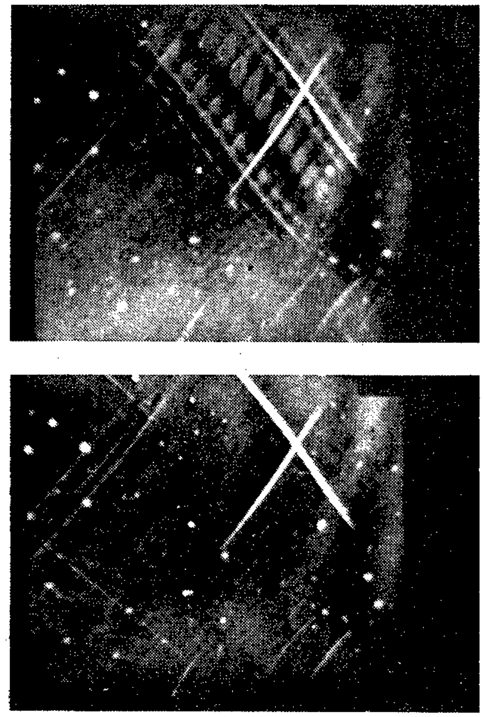
Image of a Faint Meteor on a Television Screen.

A "forbidden" green line of atomic oxygen, the aurora borealis which is well known to observers, has been observed for many faint meteors. It is called "forbidden" because the conversion of an electron accompanied by the radiation of this line cannot exist in ordinary conditions for an excited oxygen atom: the surface from which the conversion occurs is always



Spectra of a Meteor and of a Meteor Trail

Key:
- a. Meteor.
- b. The meteor's spectrum.
- c. Meteor trail.
- d. Spectrum of the meteor's trail (oxygen line).



Spectra of a Meteor (above) and of the Meteor Trail (below).

The bright line of atmospheric oxygen is visible in the spectra.

being "destroyed" by the impacts of other atoms. But in the extremely rarefied layers of the atmosphere, at altitudes of more than 80 km, the impacts of other atoms occur comparatively rarely, and the excited atom is able to radiate the green line. This line was noted in the spectra of bright meteors, but no one had expected to find it in faint meteors. And the most interesting point lies in the fact that this line has never been observed simultaneously with belts of the molecular ion of nitrogen which was just mentioned. This fact also requires explanation.

Of course the lines which belong to the atoms which make up the composition of the meteor body itself—atoms of iron, sodium, magnesium and others—are visible in the spectra. The lines of chromium, aluminum, cobalt, nickel, manganese, titanium and calcium and its single ion have been identified.

The television method of studying meteors and their spectra has revealed great promise for the study of faint meteors, which, as is known, occur much more frequently than bright ones. In particular, it is possible to arrange for the direct processing of video signals on an electronic computer, thereby making scientific results easier to obtain. All this will enable our knowledge about meteoric phenomena and meteoric matter in the solar system to be greatly amplified.

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TWENTY YEARS IN THE SIBERIAN DEPARTMENT OF THE ACADEMY OF SCIENCES USSR

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[Article by Yu. Ye. Nesterikhin, Corresponding Member of the Academy of Sciences (AS) USSR, director of the Institute of Automation and Electrometry, Siberian Department (SD), AS USSR and editor-in-chief of AVTOMETRIYA]

[Text] In 1977 the Siberian Department of the AS USSR is marking a noteworthy date. Twenty years ago the Soviet government passed a resolution on the creation of the Novosibirsk scientific center, with a complex of institutes having the purpose of assuring scientific and technological progress in the eastern part of our country through wide cooperation of the efforts of highly qualified specialists with different profiles. Today, when the SD AS USSR has "firmly occupied its place in world science" [1] and its role in the development of the national economy has become evident [2], the far-sightedness of the decision of Soviet power, adopted and implemented upon the initiative and with the personal participation of eminent Soviet scientists headed by Academician M. A. Lavrent'yev, has become evident.

In accordance with the Resolution of the Council of Ministers USSR dated 18 May 1957 and resolutions of the Presidium of the AS USSR, among the institutes of the SD AS USSR was created also the Institute of Automation and Electrometry (IAE). The organization of the institute and its work during the first 10 years were headed by its first director, Honored Worker of Science and Engineering of the Ukrainian SSR, professor, Doctor of Technical Sciences Konstantin Borisovich Karandeyev [3-5]. Since 1967 the leadership of that institute of the SD has been entrusted to me [6-8]. The main nucleus of the institute was a large group of pupils and associates of K. B. Karandeyev who transferred with him to Novosibirsk from the Institute of Physics and Mechanics of the AS Ukrainian SSR and L'vov Polytechnical Institute. The staff of the IAE of the SD AS USSR was completed with scientific workers and engineers invited mainly from Novosibirsk organizations and with VUZ graduates (especially from Novosibirsk Electrical Engineering Institute and Novosibirsk State University). A new detachment of physicists transferred in 1967 and subsequent years into the institute from the Institute of Nuclear

Physics of the SD AS USSR. The journal AVTOMETRIYA, one of the scientific and technological publications of the SD AS USSR, was founded on the basis of the IAE of the SD AS USSR [9].

From the very start of its work the institute has participated in complex investigations jointly with other institutes of the SD AS USSR (of Geology and Geophysics, of Theoretical and Applied Mechanics, of Chemical Kinetics and Combustion, of Catalysis, of Hydrodynamics, of Nuclear Physics, of the Physicochemical Principles of Processing Mineral Raw Material, of Thermophysics, etc).and actively collaborates with industrial enterprises of Novosibirsk and other cities. The work done in the institute is constantly reported on the pages of the journal AVTOMETRIYA.

Like all other subdivisions of the SD AS USSR, the institute is greeting the 20th anniversary with labor successes.

At the end of 1976 the activity of the institute was approved by the Commission of the presidium of the AS USSR. In doing so the commission noted the efforts of the institute [8,10-12] to realize the results of complex basic research by introduction into industry and considered it advisable to recommend, in implementing the decisions of the 25th CPSU Congress, that the positive five-year experience in the coordination of scientific research work and experimental design work and the effective introduction by the institute of new developments into industry through interbranch design sections be studied and made widespread.

In 20 years the associates of the institute have obtained a total of about 500 author's certificates for inventions and ten foreign patents. The institute has been awarded six certificates of the All-Union Exhibition of Achievements of the National Economy of the USSR (four of them first degree and two of the second) and associates of the institute have been awarded 54 medals of the Exhibition (four gold, 11 silver and 39 bronze).

For investigations and work done in the IAE of the SD AS USSR, 24 of its associates have received awards: an Order of Lenin, six Orders of the Red Banner of Labor, six orders of the "Badge of Honor," six medals "For Labor Valor and five medals "For Labor Excellence" (work done in the second decade of activity of the institute was noted by 16 awards).

Considering its main task to be the formulation and organization of research contributing to implementation of the decisions of the 25th CPSU Congress, the Institute of Automation and Electrometry of the SD AS USSR works on the following scientific directions: the physics of nonlinear phenomena, the fundamental principles of memory and optical data processing and the automation of scientific investigations.

The institute has published the principal results of recent work in [13-14], and the results of research of the institute have been published in greater detail in 55 monographs, 50 preprints and in scientific articles (over 1500) in many Soviet and foreign periodical and nonperiodical publications.

The journal AVTOMETRIYA, organized upon the initiative and on the basis of the institute and acting in close interconnection with it, is performing more and more successfully the task entrusted to it -- that of informing the scientific community about new directions and results in the most important areas of scientific and technological progress. For a number of years the journal has occupied one of the first places in summing up each year the results of the activity of periodical publications of the SD AS USSR. The issuance of thematic issues devoted to the most urgent areas of research has become traditional in the work of the journal. Such issues, which are greeted by specialists with special interest, would have been impossible without the active work of members of the editorial board of the journal and the leading sicentific associates of the institute.

A principal distinctive feature of the work of the IAE of the SD AS USSR at the present time is the fact that, in striving for broad cooperation of the efforts of specialists with different profiles which has served as one of the bases for the organization of Akademgorodok at Novosibirsk and has now been made the basis of a further development of science in the SD AS USSR, the institute has confidently started along the path of collectivization of scientific labor, which assures high effectiveness of complex physical and technological scientific investigations. This is one of the sources of the achievements of the institute, and important pledge of the accomplishability of its plans in the future.

In all its activity the institute, like all other institutions of the SD AS USSR, constantly feels the attention and concern of the leading party and state agencies. A new manifestation of the attention of the party and government is the resolution of the CC CPSU entitled "On the activity of the Siberian Department of the Academy of Sciences USSR on the development of basic and applied scientific research, increase of its effectiveness, the introduction of scientific achievements into the national economy and the preparation of personnel." One must feel great pride in the evaluation of the achievements of the SD AS USSR. At the same time we are deeply aware of the need to justify the high confidence.

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